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A User's Manual for a Method of Map Scanning and Digital Editing for Thematic Map Production and Data-Base Construction

By DAVID R. SOLLER, WILL R. STETTNER, KENNETH J. LANFEAR, and DOUGLAS S. AITKEN

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FIGURE

1. Diagram showing steps in digital production of maps by our method **4**

METRIC CONVERSION FACTORS

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
millimeter	0.03937	inch
meter	3.281	foot

A User's Manual for a Method of Map Scanning and Digital Editing for Thematic Map Production and Data-Base Construction

By David R. Soller, Will R. Stettner, Kenneth J. Lanfear, *and* Douglas S. Aitken

Abstract

This report describes a method of scanning manuscript maps, manipulating the digital map data, and outputting the data as color separates for map printing. The edited digital data can be used to build a data base for analysis in a geographic information system (GIS). This new combination of digital techniques was applied to an unpublished regional geologic map. We selected a Tektronix autovectorizing scanner, ARC/INFO GIS software, and a Scitex digital plotter to prepare the map separates for printing.

This method is intended to enhance existing digital map production capabilities. It is appropriate for research projects that need a digital map data base for analysis but cannot justify the time and expense of contractual services for map scanning, manual digitizing, or digital map editing. It is not necessarily the best or only approach to digital map production or creation of digital data bases; rather, it is an interim method, parts of which will soon become obsolete. Meanwhile, this method could be adopted, in part or in total, by others.

This report is organized as a user's manual, providing detailed step-by-step descriptions of the method. It is limited in scope and cannot address all the topics and user skills that are required. Therefore, it is intended for users having at least a rudimentary understanding of the various hardware and software systems involved.

INTRODUCTION

Traditionally, maps have been created, revised, and reinterpreted by hand on paper or on scale-stable base materials and then have been prepared for printing. For many maps and research projects, traditional cartographic techniques are still preferred. However, for an increasing number of map projects, digital computer technologies offer an approach to map production that holds certain advantages, such as the compilation of a digital data base that can be used for scientific analysis. In recent years, computerization of geographically referenced data has increased, and sophisticated geographic information system (GIS) software has been written to store and manipulate these data. This technology is continually improving and changing. In the past, it has not been feasible for many thematic maps, which have unique formats. Rather, computer techniques were the domain of large projects that required the handling of many data and the standardization of the format of map data. Such projects, through this standardization, achieved cost-efficient map production.

In the past few years, the growing interest in GIS and GIS data bases, supported at the U.S. Geological Survey (USGS) by its regional GIS research laboratories, has spurred research into the applicability of computer techniques to a wider range of unpublished thematic maps. One such thematic map was used to develop the combination of methods discussed in this report. That map depicts the three-dimensional framework of glacial deposits covering 25 percent of the continental United States and is referred to in this report as the "test map" and the "Quaternary sediments map"; it will be published in four sheets (Soller, in press a–d). It was originally destined for preparation by conventional cartographic techniques. Instead, a digital, computer-based approach was selected for two reasons. First, the map is large and complex, and it was judged that digital techniques would yield greater legibility than would conventional preparation of color separates (separate negatives for each color that will be used to produce the map). Second, the map data were needed in a digital format for GIS-based research.

Initially, this map project relied on a prototype method that used existing digital production capabilities at the USGS. The method was developed by C.J. Cialek (USGS, written commun., 1987) and was discussed by Utz and others (1988). The prototype method had many tasks and required numerous transfers of the map data between different computer systems. Much time was needed for reformatting and computer processing, and operator costs

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were high. Because of more recently developed hardware and software, parts of that method are now obsolete. However, the prototype method is briefly described in this report (see appendix) to provide a historical perspective on the evolution of digital map production.

For the Quaternary sediments map, we wanted a more cost-effective method that could make use of new hardware and software. We also desired more control over the scheduling and performance of data processing and editing. In developing the new method, two objectives were addressed: first, an informal, readily accessible means for individual scientists to acquire digital data from unpublished maps in order to conduct digitally based research, and, second, more efficient methods of manipulating digital manuscript maps and of converting manuscript maps into color separates for printing.

For our method, we chose to scan the Quaternary sediments map on a Tektronix autovectorizing scanner, a relatively low cost device that captures linework at acceptable levels of resolution. Manual digitizing was not considered a viable option because of the large format of the Quaternary sediments map and the need for rapid production with high levels of accuracy. We chose to use ARC/INFO GIS software (a product of ESRI (Environmental Systems Research Institute), Inc., Redlands, Calif.) for data manipulation because it fulfills our requirements and because it is commonly used at the USGS. Scitex equipment was used to process and plot the color separates because it has a high level of resolution, produces high-quality printing screens, and can plot complete negatives for large-format maps (having maximum dimensions of about 40×73 in.). All work except Scitex processing can be done by scientists with equipment open to general use in the GIS research laboratories of the USGS.

Like the prototype method, ours is an interim method, parts of which will soon become obsolete. In the rapidly changing field of digital mapping and cartography, the evolution of methods and equipment is both commonplace and welcome. In time, our method's primary value will be to document one small part of that evolution.

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BACKGROUND DISCUSSION

Justifications for a Digital Approach to Map Production

Digital techniques for map production are continually being created and refined by many individuals and organizations. In the past, production costs at the USGS for digitally produced thematic maps have been significantly greater than those for conventionally prepared maps. However, these costs cannot be fairly compared because digital techniques have yet to be standardized; each digitally produced thematic map has, in essence, been a methods-research project. The need to print the Quaternary sediments map has resulted in two new production methods: the prototype method and the method described in this report. Because the Quaternary sediments map has not yet been printed, publication costs (including costs for all phases of the digital procedure) are not known. However, costs for map scanning and assigning attributes to map features according to our method are significantly less than those costs for the prototype method. As existing methods are refined and new ones are developed, digital map production costs should continue to decline.

For many thematic maps, the most significant reason to produce a map by digital techniques is that a digital data base is created by the process. This data base can have many uses whose importance may overshadow that of the printed map. Unlike the printed map, the data base is dynamic. It can be updated and reinterpreted, and a revised map or a derivative map can be published with relatively minor effort or expense. The data base can be analyzed in conjunction with other data bases to provide information in support of scientific research or interdisciplinary topics, such as land-use and environmental management.

Another reason for printing maps from digital data is that the inherent precision of digitally produced color separates permits a greater level of map detail than that possible by conventional techniques: more complex map units and patterns are possible, and the author can have greater control over map colors and appearance. Digital map production can, therefore, encourage the design of new types of maps incorporating different and more effective approaches to data presentation.

The Test Map

The test map used to develop both the prototype method and our method is a 1:1,000,000-scale manuscript

map showing Quaternary deposits for the glaciated area of the United States east of the Rocky Mountains (Soller, in press a–d). Parts of southern Ontario, areas beneath the Great Lakes, and parts of the submerged eastern seaboard are also shown on the map. The map shows the character of sediments exposed at the surface, the thickness of Quaternary sediments, and where possible, certain buried Quaternary units. This map is very large, and it requires the use of scratch boundaries (lines that are not intended for plotting but that are used to separate areas filled by different colors) and blocked-out areas (areas where a color is blocked out beneath pattern elements to allow another color to print). The use of scratch boundaries and blocked-out areas requires precise registration during printing, and it was determined that conventional map production methods would not give satisfactory results for a map of this size and detail.

The Quaternary sediments map spans four map sheets and has an overall size of roughly 4×12 ft. The largest sheet is approximately 42×55 in. The topographic base map on each sheet is composed of a hand-mosaicked group of 4°×6° quadrangles from the International Map of the World Series or Army Map Service 1:1,000,000-scale maps; all these maps are available from the USGS. Because each quadrangle has unique map projection parameters, and because these map sheets include as much as 12° of latitude and longitude, a precise mosaic is impossible. In order to preserve the registration of the geologic information to the base map without sacrificing the spatial integrity of the digital data base, entire map sheets were not scanned. Rather, the four layers of geologic information shown on the map (character of sediments exposed at the surface, thickness of Quaternary sediments, buried units and surface veneer units, and miscellaneous point and line information) were scanned separately for each 4°×6° quadrangle, and the scanned data were recombined on the base map.

We designed and tested our method on the smallest of the four map sheets (Soller, in press d). This sheet is composed of four 1:1,000,000-scale quadrangles, shows the continentally glaciated parts of Montana and western North Dakota, and has a physical size of about 12×32 in. Because the sheet contains mapped areas on small parts of four adjoining quadrangles, we decided to scan the entire sheet in one piece, and we selected map projection parameters that were a compromise for the four quadrangles. We required 59 hours to scan, edit, and prepare the map for Scitex processing (steps 1–13 discussed below).

Line Accuracy and Scanner Resolution

Planning a new method to supersede the prototype required adoption of new equipment as well as new techniques. The most significant change in hardware was the use of a Tektronix scanner that is accessible to general users. It is a relatively low cost device, and it has lower resolution than the Scitex scanner. The Tektronix scanner operates at a resolution of 0.0833 mm (0.00328 in.). In Scitex pixels, this translates to a resolution of 12 pixels per millimeter, which, in Scitex terminology, is denoted as RES12. Although the Scitex can operate from RES4 to RES47, a resolution of RES17 (or sometimes RES34) is commonly used for thematic maps.

In order to compare output from the two scanners, we performed a Scitex RES17 scan of the map area scanned by the Tektronix. Because the Tektronix-scanned data had been edited on the Tektronix workstation and in ARC/INFO and had been projected, transformed, and combined with other map data in ARC/INFO, we were not able to directly compare the raw, scanned data. The Tektronix-scanned data, which were manipulated as required to create the fully edited data base, could not be expected to preserve the line positions exactly as scanned. Nevertheless, we compared Scitex-generated film plots of both the Scitex and Tektronix scans by visual inspection. This comparison indicated that the scribed lines (on the scan copy) were as faithfully reproduced by the Tektronix scanner as by the Scitex scanner.

Despite the results from our visual comparison of the scans, the lower resolution of the Tektronix may concern some users. The lower resolution may seem to indicate that the Tektronix scanner will produce digital lines whose positional accuracy is unacceptably low. However, for most thematic maps, the resolution of the scanner is high compared to the precision with which a line can be placed on the map by the author, in part because lines on thematic maps are interpretive. As a geologic map is being constructed, the author must consider a variety of information from a number of sources to determine where lines will be drawn. Because the geologist must postulate and rely on stratigraphic, temporal, and process-oriented models to explain the fragments of physical information available, geologic contact lines are interpretive features that have a certain amount of positional uncertainty. This uncertainty may or may not be constant and definable for the entire map. Lines are especially interpretive on maps of smaller scale, such as the Quaternary sediments map. In addition to these inherent uncertainties in line position, small changes in line location are introduced by conventional scribing or digital plotting for map printing. On the basis of these considerations, we think that the lower resolution of the Tektronix scanner is not significant for thematic maps.

OUR METHOD

Our method is based on three hardware and software systems: the Tektronix 4991 autovectorizing scanner and editing workstation, ARC/INFO running on a Prime computer, and the Scitex Response-280 editing workstation and plotter. All steps before Scitex processing are controlled by the user (for example, the project scientist or map editor).

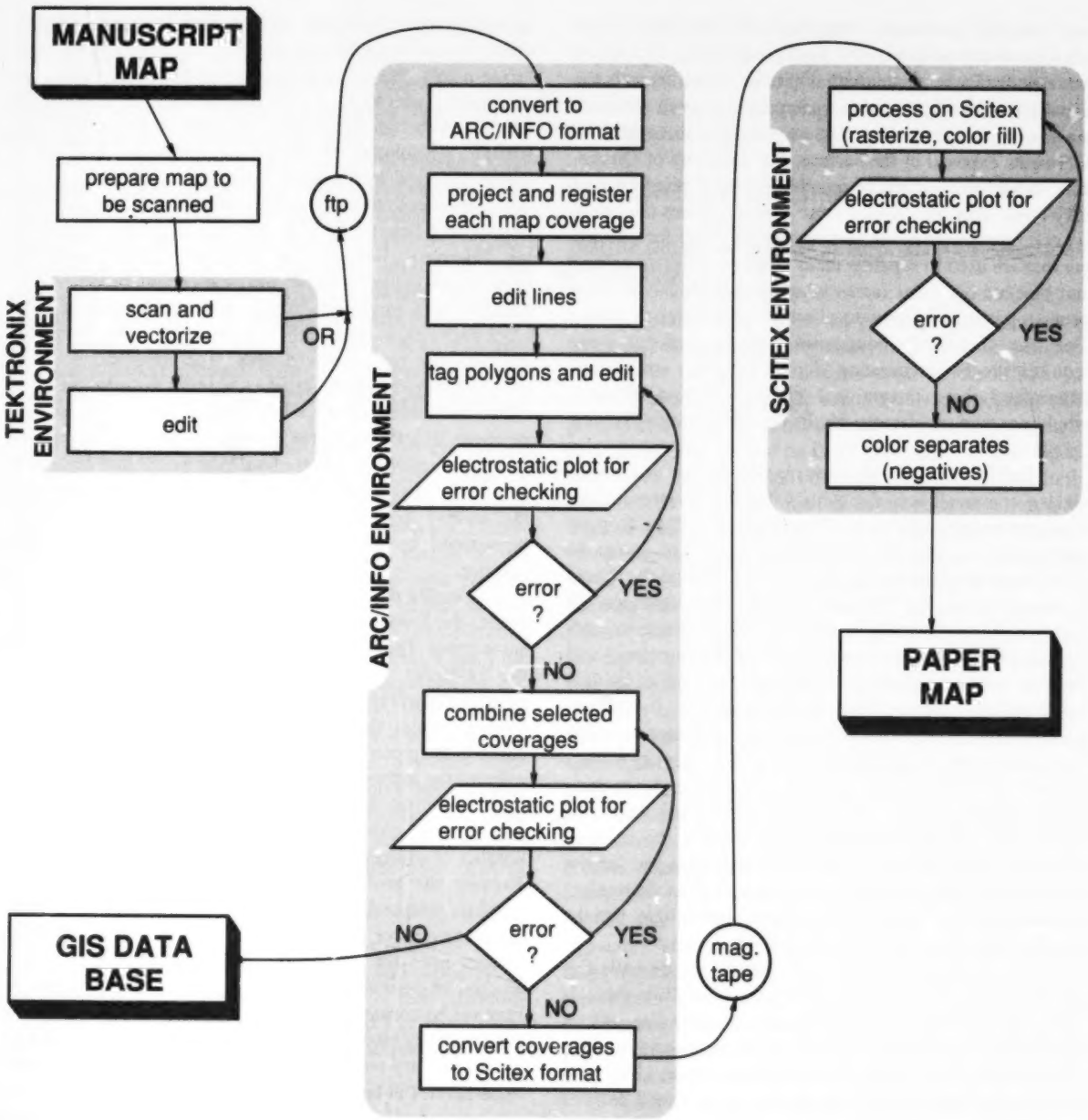

Figure 1. Steps in digital production of maps by our method. GIS, geographic information system; ftp, file transfer protocol, a means for electronic data transfer; mag., magnetic.

The method is summarized below and in figure 1:

(1) Author linework or scribed copy is scanned on the Tektronix 4991 autovectorizing scanner and automatically recorded onto the disk of the Tektronix editing workstation.

(2) For each map separate, scanned linework is partially edited on the Tektronix workstation by using TekniCAD software. Map symbols and their leaders are removed, and most gaps in lines are repaired. This step may be omitted, and all editing may be done in ARC/INFO; the choice depends on the availability of equipment, the expertise of the editor, and the operations to be performed.

(3) Edited map files are transferred by Ethernet cable and ftp (file transfer protocol) software to the computer

that contains the ARC/INFO GIS software. If Ethernet is not available, Kermit software can be used.

(4) Files are converted to ARC/INFO line coverages by a routine written by one of the authors (Lanfear). System software written since our method was established permits conversion of TekniCAD files to IGES (Initial Graphics Exchange Specification) format on the Tektronix workstation by the TCADIGES command and conversion of the IGES-format files to ARC/INFO coverages by the IGESARC command (T.T. Fitzgibbon, USGS, oral commun., 1990).

(5) Prior to line and polygon editing, all coverages for a given map (for our test map, all coverages for a 1:1,000,000-scale quadrangle) must be precisely registered to each other; if necessary, the TRANSFORM command in ARC or the ADJUST command in ARCEDIT may be used. As part of this registration procedure, coverages are transformed to the appropriate map projection.

(6) Lines are edited in ARCEDIT to ensure their continuity. Lines must be continuous before the correct polygon topology can be established. Editing efficiency is improved by using an AML (Arc macro language) program with pulldown menus, which was written by one of the authors (Lanfear).

(7) Polygon topology is built, label points are placed in each polygon, and items are added, as needed, to the newly created polygon attribute table (.PAT). Polygon label points are assigned values, or tagged, by using the tag subroutine of Lanfear's ARCEDIT AML or another method, as discussed in section F–4.

(8) The validity of map data is checked in ARCPLOT on a graphics display terminal. After any errors have been corrected in ARCEDIT, electrostatic plots are generated for a final check.

(9) Two coverages, character of surficial deposits and thickness of Quaternary sediments, are combined so that resultant polygons contain information from both coverages and can, therefore, be assigned unique map colors. Coverage items are renamed as appropriate, the coverages are merged with the UNION or INTERSECT command, and sliver polygons are removed with the ELIMINATE command.

(10) The validity of map data is checked in ARCPLOT on a graphics display terminal. After any errors have been corrected in ARCEDIT, electrostatic plots are generated for a final check.

(11) At this point, coverages can be developed into a GIS data base (not discussed in this report).

(12) Coverages are converted to Scitex format with the ARCSCITEX or PLOTSCITEX command.

(13) Files are written to magnetic tape.

(14) Files are read onto the Scitex system for generation of negatives. This procedure can be lengthy and complex; it is briefly discussed in this report.

About the User's Manual Format and Syntax

Because this report is a user's manual, we have provided certain instructions on basic system commands and operations, such as operation of the autovectorizing scanner. These instructions are generalized; for further information, see the user documentation provided by the manufacturers. We assume that the user has at least a rudimentary knowledge of general map and cartographic concepts (for example, map projections), the PRIMOS and UNIX operating systems, graphics terminals, ARC/INFO, and file management concepts. General skills such as reading and writing to magnetic tapes, for file backup or for transfer of map data to other computer systems, are beyond the scope of this report.

In this manual, all system and user dialog is indented and set off from the text by spaces. System prompts and information appear in normal (roman), uppercase and lowercase letters. For the Tektronix scanner and workstation, the system prompt in this manual is "system prompt>"; for PRIMOS, the system prompt is "OK,"; for ARC, it is "Arc:"; and for INFO, it is "ENTER COMMAND>". Within the system-user dialog, notes or instructions to the user are shown in *italics*. Commands entered by the user appear in uppercase **BOLD** type, except for the Tektronix commands, which appear in lowercase **bold** type. Command variables commonly appear in lowercase and are confined between angle brackets, < >. These command variables include file and coverage names. They can be entered in either uppercase or lowercase in ARC or in PRIMOS and are reported by these two systems in uppercase. In INFO, all commands and variables must be entered in uppercase letters. On the Tektronix, all commands and variables must be entered in lowercase letters. A carriage return (the return key) is shown as <cr>.

A. Preparing for Map Scanning

If the map to be scanned has dense, continuous lines of uniform thickness, then the digital map editing can be quick. Therefore, an author's lines may need to be scribed prior to scanning. In devising our method, we scribed the author's lines in order to minimize editing problems. Lines were scribed with a thickness (weight) of 0.004 in.; negatives that were used as scan copies had line weights of 0.004–0.005 in. Thinner lines were tried (for example, 0.002 in.), but they did not scan well; the lines were recorded as broken line segments because they were too thin to be consistently detected by the scanner, which has a resolution of 0.00328 in. (0.0833 mm). A thicker line was not used because of the tight spacing of the linework.

Latitude and longitude marks were added to each map separate for registration purposes; the marks were small crosses, not a grid of lines.

For some maps, the author's linework may be scanned with good results. Choice of the type of scan copy is a matter of judgment and economy: if the author's linework is complex, or if the time allotted for editing is limited, scribing the linework is appropriate because it will yield a higher quality scan copy that needs relatively little editing. Aronoff (1989, p. 107) noted that map preparation (that is, redrafting or scribing) before manual digitizing can reduce the costs of digital capture by as much as 50 percent. If linework is not too complex, and if time and personnel can be allotted for map editing, it can be appropriate to use author's linework as the scan copy. We experimented with scanning the author's linework for the smallest sheet of the Quaternary sediments map and achieved satisfactory results because the linework was relatively dense and continuous. The author's linework has since been used as the scan copy for other parts of the Quaternary sediments map.

B. Map Scanning

B–1. Getting Started

We used a Tektronix 4991 autovectorizing scanner, which is connected to a UNIX-based Tektronix model 4325 graphics workstation with graphics tablet. The workstation stores Tektronix scanning software (TekScan) and editing software (TekniCAD). TekScan controls all scanning operations and converts scanned data from raw vector format (.VEC file extension) to TekniCAD format (.TDA file extension). This scanning workstation is easy to use and can provide high-quality map data for GIS data bases and for thematic graphic reproduction. It is used in several USGS locations, and where one is housed in a USGS regional GIS research laboratory, it is accessible to all trained users.

Before starting the scanning procedure, consult personnel responsible for the equipment and obtain their approval to operate it. To scan a map, log onto the workstation, and load the scan copy onto the scanner drum. Do not block the groove on the drum near its right edge, as the groove must be clear for the scanner to operate properly. If a negative or a clear-film positive is used, place the emulsion side against the drum for the better scan. Next, initiate the TekScan software:

system prompt> **tekscan** <**cr**>

This command causes the TekScan Main Menu to be displayed. The user responds to all TekScan menus by entering the number corresponding to the desired choice. The return key is not required when choosing from the menus.

B–2. Setting the Scanning Parameters

The user should select appropriate values for scanning parameters to optimize the quality of the digital output. Although default settings for scanning parameters are provided by TekScan, they are not optimal for most scan copies and should be used only as a guide. The user must modify the parameter settings to suit the copy medium and the quality and complexity of the linework. To view and modify the scanning parameters, select option 1 on the Main Menu to access the Scanner Control Menu:

Main Menu

1. Change Parameters
2. Start Scan and Convert VEC File to TekniCAD TDA File
3. Start Scan
4. Convert Scanned VEC File to TekniCAD TDA File
5. Convert Scanned VEC File to GSS PIX File
6. Convert GSS PIX File to TekniCAD TDA File
7. Exit

Please choose one of the above: **1**

After option 1 is selected, the Scanner Control Menu is displayed:

Scanner Control Menu

1. Show Scanning Parameters
2. Change Scanning Parameters
3. Show Drawing Environment Parameters
4. Change Drawing Environment Parameters
5. Show Communication/Display Parameters
6. Change Communication/Display Parameters
7. Read all Parameter Files (.TSS,.TSE,.TSC)
8. Save all Parameter Files (.TSS,.TSE,.TSC)

Please choose one of the above: **2**

After option 2 is selected from the Scanner Control Menu, the Scanning Parameters Menu is displayed; default parameters can be viewed and changed by selecting option 2.

Scanning Parameters Menu

1. Read Scanning Parameters from a File (.TSS)
2. Enter New Scanning Parameters
3. Save Current Scanning Parameters to a File (.TSS)

Please choose one of the above: **2**

The following menu will appear:

Scanning Parameters

1. Scan Units : Metric
2. Background Type : Light

```
3. Dot Trapping Size          : 5×5 pixels
4. Void Trapping Size         : 1 pixel
5. Smoothing                  : Enabled
6. Reflectance Threshold      : 42%
7. Growing Layers             : 0
8. Thinning Layers            : 2
9. Scan Area                  : 100.00, 300.00,
                                100.00, 300.00
A. Vectorizing Tolerance      : 0.097
B. Short Vector Length        : 0.000
C. Short Vector Tolerance     : 0.000
D. Bell                       : Enabled

Please choose one of the above:
```

The default settings appear to the right of the colons. These default settings vary because users can redefine them. If option 1 had been selected from the Scanning Parameters Menu, then parameter settings would be read and displayed from a preexisting parameter file (.TSS).

From this menu, the user can customize the parameter settings for each scan. Consult the Tektronix user's manual and operator's manual for complete information on the scanning parameters. Parameter settings can be modified in any order and can be modified more than once before exiting this menu. Certain parameters have only two possible settings, and the user can only alternate between the two settings by selecting that option number. Other parameters (for example, see "Reflectance Threshold" and "Scan Area" below) can accept a range of settings. The optimal settings depend on a number of factors, including the condition of the image to be scanned. To determine the best setting for parameters such as Reflectance Threshold, use the Scan Area parameter to select a small area of the image to scan as a test. Through an iterative series of test scans, optimal parameter settings can be determined. If you decide to use default settings, return to the Main Menu with the escape key. To retreat toward the Main Menu, one menu at a time, use the delete key. The scanning parameters are described below:

Scan Units.—Choices for Scan Units are **Metric** (millimeters) or **English** (inches). The choice can be important to subsequent data-processing steps; map data are scanned in units of the chosen measurement system, and the unit of measure is retained in TekniCAD and in output files.

Background Type.—Choices for Background Type are **Light** or **Dark**. Select **Light** for scanning positives, **Dark**, for negatives. Opaque media (paper copies) should be positioned on the drum face up; transparent media (negatives or clear-film positives) should have the emulsion against the drum surface. If placement of the appropriate side against the drum causes the map to be inverted (that is, if the map's east side is on the left side of the drum and if the south side is facing upward), then the Mirror Image parameter in the Communication/Display Parameters Menu must be set to **On** (see section B–3, "Setting Other Parameters").

Dot Trapping Size.—Discrete points of scanned information smaller than the selected Dot Trapping Size will be deleted automatically. This function is useful for deleting the scanned images of dust specks, which commonly adhere to the scan copy or drum. Choices are **1×1**, **3×3**, or **5×5** pixels. Because pixels are quite small (0.0833 mm or 0.00328 in. square) relative to thematic map linework, the maximum Dot Trapping Size (**5×5** pixels) is recommended.

Void Trapping Size.—Voids in linework are filled automatically. Size options for Void Trapping Size are the same as those for Dot Trapping Size. We used **1×1** pixel for Void Trapping Size because our lines were thin and our linework was closely spaced.

Smoothing.—Choices for Smoothing are **Enabled** or **Disabled**. We recommend that Smoothing be enabled, which will cause 1-pixel-wide protrusions or indentations to be removed. The autovectorizer does this processing task after void and dot trapping.

Reflectance Threshold.—The scanner determines what will be written to the digital file by comparing the reflectance of the pixel currently being scanned to the reflectance of the background. Reflectance is the ratio of reflected to incident light. The scanner senses linework on a map by bouncing a beam of light off the map and into a detector. If light reflected from the pixel is above the threshold value for dark Background Type or below the threshold value for light Background Type, then that pixel will be written to the digital file. Otherwise, that pixel will be considered to contain no data (for example, not part of a geologic contact line). For a light background map such as a clear-film positive with black linework, the background (actually the white drum surface behind the clear film) will reflect more light than the linework. Therefore, for light background types, the linework will have relatively low reflectance and can be recorded to the digital file only if the reflectance threshold is sufficiently high. If the threshold is set too high, dirt smudges and perhaps even the film positive itself will be detected and recorded. This parameter affects the quality of the scan more than most, and its setting should be carefully determined by one or more test scans on a small part of the map (see "Scan Area" parameter discussion below).

The Reflectance Threshold can be set from **0%** to **100%** because the reflectance ratio is expressed as a percentage. For scanning a positive image, the threshold should probably be set between **40%** and **50%**. If the threshold is set too low, then line breaks will result. If the threshold is set too high, then tightly spaced lines will become fused together or will be bridged by short lines. For scanning a negative, the threshold should probably be set between **25%** and **30%**. For negatives, lower thresholds will cause fusing or bridging of tightly spaced lines, and higher thresholds will result in line breaks.

Growing Layers.—In the Growing Layers procedure, a layer of pixels is added to all edges of scanned data, including lines and filled areas. Choices are **0**, **1**, or **2** layers of pixels. Adding layers of pixels will fill gaps within lines but may also fill gaps between tightly spaced lines; these filled gaps require additional editing time. On our scribed test map, high-quality lines had few irregularities and breaks. The scribed lines had a width of 0.004 in., which is quite narrow and close to the resolution of the scanner. For lines of this thickness and quality, we recommend setting the Growing Layers parameter to **0** pixels. The autovectorizer performs this processing task after Smoothing.

Thinning Layers.—The Thinning Layers procedure removes layers of pixels from both sides of a line; the maximum reduction is to a line 1 pixel wide. This processing occurs after the Growing Layers procedure is completed for a line. Choices are for the removal of **0** to **7** pixels from each side of the line's center. Line gaps and areas filled during the growing operation are not affected by thinning. If lines are thinned too much, line spurs form, and T-shaped intersections may become distorted into Y-shaped intersections. On our scribed test map, lines had a width of 0.004 in., which is quite narrow and close to the resolution of the scanner. For lines of this thickness, we recommend that the Thinning Layers setting be no more than **2** pixels greater than the Growing Layers setting (for our map, this meant a Thinning Layers setting of **2** or less). However, if thicker lines are to be scanned, then a higher Thinning Layers setting must be used to thin the lines to 1-pixel width. This thinning is necessary so that the autovectorizer can accurately convert the scanned line into a single vectorized line that traces the centerline of the scanned line. If a scanned line is much wider than 1 pixel, the autovectorizer cannot do this accurately, and it may produce a series of vectorized lines arranged as small boxlike forms or networks that together may imitate the form of the scanned line.

Scan Area.—The Scan Area parameter defines the area to be scanned. This area may include the entire scan copy or a small portion of the copy. The optimal scanning parameters are selected by trial and error, and so it is useful to specify a small test area on the map that can be quickly scanned. In a series of trial scans within the test area, parameter settings can be varied and optimized. Upon selecting the Scan Area parameter, the user is prompted for the scan area, whose dimensions are measured along the edge of the loading platform (the x-axis) and the left edge of the scanning drum (the y-axis). Dimensions must be defined in the scan units specified (millimeters or inches). The maximum scanning format is 870×1,200 mm (34.5×47 in.).

Vectorizing Tolerance.—The Vectorizing Tolerance parameter sets the maximum perpendicular distance between a line on the scan copy and the vector that represents that line. By selecting values from **0** to **10** mm or **0** to **0.5** in., the user determines how closely the vectors are to follow the original shape of the line. If the tolerance is set too high, then the vector data will have an angular appearance, and detail will be lost. If the tolerance is set too low (for example, below the scanner's limit of resolution, which is 0.0833 mm or 0.00328 in.), then the vector data may have a ragged or stairstep appearance caused by the vectors following the edges of pixels. Intermediate settings should provide acceptable line quality. However, because this parameter determines the amount of data needed to describe a line, file size varies as the inverse of the parameter setting. The appropriate setting is generally a compromise between the line quality and file storage limitations. For the map data from our test area, a tolerance ranging between **0.1** and **0.095** mm provided lines with adequate detail and acceptable file size. However, for other types of maps, greater detail is required to preserve certain images. For example, to retain the accuracy and detail of strike and dip symbols on a map, a smaller tolerance may be needed.

Short Vector Length.—The Short Vector Length parameter sets the maximum length for lines to be classified as short vectors. The range of values is from **0** to **50** mm (**0** to **1.97** in.). This parameter can be set to select features such as depression contour tic marks and save them to a file separate from the contour lines. For our test map, and probably for many other maps as well, this capability is not needed; select **0.0** if this procedure is not desired.

Short Vector Tolerance.—The Short Vector Tolerance parameter is similar to the Vectorizing Tolerance parameter. Select **0.0** if the Short Vector Length is set to **0.0**.

Bell.—Choices for the bell are **Enabled** or **Disabled**. If enabled, a bell will sound to verify the communication link between the autovectorizer and the workstation, to alert the user when scanning errors occur, and to signal completion of the scan.

B–3. Setting Other Parameters

After scanning parameters have been set, they can be saved to a parameter file. Return to the Scanning Parameters Menu by pressing the delete key. Save the parameter settings to a parameter file (.TSS) by selecting option 3 and specifying a file name. Otherwise, return to the Main Menu by pressing the escape key.

The user may also want to modify certain default Drawing Environment or Communication/Display parameters. If so, choose option 1 from the Main Menu to reach the Scanner Control Menu. From the Scanner Control Menu, a number of drawing and communication/display options may be selected. The Drawing Environment parameters may need to be modified if the scanned data will be separated into two layers, one for short vectors and one for long vectors; for general scanning of linework, however, the default values should be used. Choose option 6 from the

Scanner Control Menu to view and change the Communication/Display parameters:

```
Scanner Control Menu
----------------------------------------
    1. Show Scanning Parameters
    2. Change Scanning Parameters
    3. Show Drawing Environment Parameters
    4. Change Drawing Environment Parameters
    5. Show Communication/Display Parameters
    6. Change Communication/Display Parameters
    7. Read all Parameter Files (.TSS,.TSE,.TSC)
    8. Save all Parameter Files (.TSS,.TSE,.TSC)

  Please choose one of the above: 6
```

After option 6 is chosen from the Scanner Control Menu to display the Communication/Display Parameters Menu, default parameters can be viewed and changed by using option 2:

```
Communication/Display Parameters Menu
----------------------------------------
    1. Read Communication/Display Parameters
       from a File (.TSC)
    2. Enter New Communication/Display Param-
       eters
    3. Save Current Communication/Display Param-
       eters to a File (.TSC)

  Please choose one of the above: 2
```

The following menu will appear.

```
Communication/Display Parameters
----------------------------------------
    1. TTY Port                          : 00
    2. Debug                             : Off
    3. Baudrate                          : 9600
    4. Display Scanned Image             : On
    5. Long Vector Color (1-8)           : 1
    6. Long Vector Filled Area Color (1-8) : 3
    7. Short Vector Color (1-8)          : 5
    8. Short Vector Filled Area Color (1-8) : 4
    9. Mirror Image                      : Off
    A. Rotate Image (Degree)             : 0

  Please choose one of the above:
```

Default values are generally acceptable. If, however, the map must be inverted on the drum for optimum scanning (see the "Background Type" discussion above in section B–2, "Setting the Scanning Parameters"), then the Mirror Image option must be set to On. If, because of size, the scan copy cannot be placed on the drum with north pointing upward, use the Rotate Image option to position north to the top of the display screen if this is the desired viewing position. The system performs the Mirror Image conversion before the Rotate Image step; this sequence must be considered by the user in order to select the proper rotation angle. The Display Scanned Image option should be set to Off for background scanning (see discussion below); otherwise, it is commonly set to On in order to monitor the scanning progress.

B–4. Initiating the Scan

After all parameters have been set, return to the Main Menu and do the following:

(1) Select option 2 ("Start Scan and Convert VEC File to TekniCAD TDA File")
(2) Reply to system prompt for file name.

Information on scanning progress is displayed during the scan. After the scan is complete, the Main Menu appears. The user commonly resets scanning parameters for the same copy or for a new scan or exits TekScan (select option 7).

B–5. Background Scanning

TekScan is commonly invoked interactively, and parameters are specified via the keyboard. While scanning, the workstation remains locked and cannot be used for any purpose other than to display the map as it is being scanned. Background scanning allows the user to run TekScan and, at the same time, to keep the workstation free for other activities, including file management, file transfer, and file editing in TekniCAD. Background scanning is made possible by creating a batch file that holds the responses to TekScan menus and prompts. The batch file consists solely of those numbers, letters, and special characters required to modify the system default parameters and run TekScan. To determine the batch file contents, the user must document, during a trial run, all the required TekScan responses.

In the batch file, the commands could be arranged as follows:

```
1222625
9250
730
200
850
^[1624 ^[2filename
7
```

The scanning session begins on the batch file's first line, with selection of option 1 (Change Parameters) from the Main Menu, then option 2 (Change Scanning Parameters) from the Scanner Control Menu, then option 2 (Enter New Scanning Parameters) from the Scanning Parameters Menu. The fourth number changes option 2 (Background Type) from light (this system's default value) to dark in order to scan a negative. The next number, 6, selects option 6 (Reflectance Threshold), and the last two digits, 25, set the threshold at 25%. To enter the reflectance threshold, a carriage return is required, and it causes additional scanning

parameter data to appear on the second and subsequent lines. The second line contains the Scan Area option (9) and the lower (left) x-coordinate in the default scan unit (millimeters), followed by a carriage return. The next three lines contain the upper (right) x-coordinate, the lower y-coordinate, and the upper y-coordinate, respectively. The sixth line concerns commands issued from the Main Menu, which is reached with the escape key. The escape command sequence "^ [" is entered by typing "control-v" and the escape key. The sequence "1624" accesses the Communication/Display Parameters Menu and sets the Display Scanned Image option to Off. The Main Menu is again reached with the escape sequence, and option 2 (Start Scan and Convert VEC File to TekniCAD TDA File) is chosen. A user-defined file name is then specified, followed by a carriage return. The last line of the file selects option 7 (Exit TekScan).

The UNIX vi editor can be used to create and edit the batch file. Invoke the vi editor as follows:

system prompt> **vi** <**batchfilename**> <**cr**>

The command must be given in lowercase letters, as required by the UNIX operating system. The screen will be blank except for a column of tildes (~) running down the left side. The vi editor has two modes, the command and the text edit mode. The command mode is active when the vi editor is started. To create the batch file, enter characters while in the text edit mode, which is commonly invoked with the "i" key. The following commands are commonly used to enter the text edit mode and to add text:

i	inserts text before cursor
I	inserts text at the beginning of line
a	appends text after cursor
A	appends text at the end of line
o	opens a new line below cursor
O	opens a new line above cursor
cw	allows changes from cursor to end of word
C	allows changes from cursor to end of line
cc	changes entire line

Characters entered after any of these input commands will write to the screen To revert to command mode, press the escape key.

Other commands reposition the cursor, delete text, and save the file. Commonly used commands are listed below:

h	moves cursor left
l	moves cursor right
j	moves cursor down
k	moves cursor up
x	deletes single character
dw	deletes word
dd	deletes line
D	deletes from cursor to end of line
:wq	saves file and quits vi
ZZ	saves file and quits vi

Initiate the batch file as follows:

system prompt> **tekscan** < **batchfilename** >
<**logfile**> **&**

A logfile must be specified, which will receive dialog such as scan menus and batch file commands. As an exception to this manual's syntax rules, "batchfilename" must be enclosed by blank spaces and angle brackets in this command only.

C. Preliminary Editing Using TekniCAD

C–1. Getting Started

TekniCAD software allows the user to inspect and edit a scanned graphic. This is an interactive, menu-driven program, and it is invoked as follows:

system prompt> **teknicad** <**cr**>

TekniCAD displays three separate active areas on the workstation screen. The top display informs the user of functions being performed and of pen, level, and dash settings. The bottom display shows menus, messages, and options for which responses are required. The large center area is for the graphic display. Menu options can be selected by using the keyboard or by pointing to the command with the graphics tablet puck and pressing the yellow button on the puck. The puck can also be used for editing.

The terminology used to describe lines is somewhat different from that used by ARC/INFO. A line (an arc in ARC/INFO) is composed of straight line segments; adjacent segments are separated by a point (a vertex in ARC/INFO).

C–2. Displaying the Scanned Image

To display a scanned image, enter the file name. If the file name is not known, enter "?" for a directory listing. In the directory, scanned images will be listed as "<filename>.TDD" (binary form) and "<filename>.TDA" (ASCII format) files. Enter the file name precisely as listed in the directory, and put the .TDA extension in uppercase letters. If the file doesn't exist, then a new one will be created. Press "?" for directory list or function key 4 for options:

<**filename.TDA** (or "**?**")> <**cr**>

The file will then be loaded into memory and drawn to the screen; the lower left corner of the screen is used as the origin. The TekniCAD Main Menu will appear in the

lower display window. To center the image and make it fill the screen,

(1) Select menu option 6 (Window/Grid). This will display the Select Window/Grid Function Menu.
(2) Select menu option 3 (Min/Max) to redraw the image at maximum size.

To view the image in more detail, local (hardware) zoom and pan can be performed at any time with function key 5. A menu will appear that gives the user various options and instructions. To zoom into an area, use the yellow button on the puck, or use the spacebar, to set the lower left and upper right corners of the area to be viewed in more detail. After the zoom operation, the system will revert to the last active menu. Press the escape key if access to the Main Menu is required.

Local zoom and pan capability provides an essential tool for editing linework. However, for many maps, especially large ones with tight linework, local zoom and pan capability does not provide adequate resolution for identifying and editing features. Resolution at high magnification can be maximized by using the Window/Grid option to view an enlarged part of the map without loss of resolution. The local zoom and pan can then be used for slight magnification as needed to edit specific lines. This technique is similar to the ARC/INFO Mapextent and hardware zoom and pan technique described in section E–3. Proceed as follows:

(1) Select option 6 (Window/Grid) from the Main Menu.
(2) Select option 1 (Box).
(3) With the puck, set the lower left and upper right corners of the window area.
(4) Use local (hardware) zoom and pan, as needed, to edit the map.
(5) Select option 3 (Min/Max) to redisplay the entire map.

The user can create and save several windows for a map area in order to systematically edit the map in detail. To do so, select option 5 (Save), and designate a window number (as many as eight windows are allowed for each map). Use option 6 (Restore) to draw a window to the screen. Use option 3 (Min/Max) to redisplay the entire map after creating windows.

C–3. Deleting Lines

To edit the linework, go to the Main Menu (press escape key if necessary). Use the following steps in order to select and color, or tag, lines that must be deleted:

(1) Select option 2 (Delete/Copy/Edit).
(2) Select option 3 (Modify).
(3) Select option 3 (Pen).
(4) Select a number to indicate pen color; for example, "<**2** *(red)*> <**cr**>."

To identify lines and spurious information (for example, dust specks detected by the scanner) to be deleted by a subsequent set of commands:

Select option 7 (Region).

Then use the yellow button on the puck, or use the spacebar, to set the lower left and upper right corners of the box. Lines that lie completely within the boxed area will then be colored (red if pen color 2 was selected, as above). To select a new region, press any key to proceed.

If it is later noted that a line has been incorrectly tagged for deletion, the line can be recovered by retagging it with pen color 1, the default color. To reassign the pen color, retreat two operations by using the green button on the puck or the keyboard's delete key to locate the Modify Function Menu. Reassign the pen color to 1, and select the appropriate line or lines with the Region option.

To delete tagged lines, press the escape key to return to the Main Menu. Choose the Delete option and the pen color of the lines to be deleted:

(1) Select option 2 (Delete/Copy/Edit).
(2) Select option 1 (Delete).
(3) Select option 3 (Pen).
(4) Select a number to indicate pen color.
(5) <cr>

The system then prompts the user to specify the lower left and upper right corners of a box (by using the yellow button on the puck or the spacebar) that contains all the lines tagged (colored) for deletion. When the upper right corner is specified, all tagged items are deleted. Next, press any key. Define more boxes and delete lines or press the escape key to leave this function.

To delete single segments from either end of a line, return to the Main Menu and do the following:

(1) Select option 2 (Delete/Copy/Edit).
(2) Select option 3 (Modify).
(3) Select option 1 (Item).

This selection displays a cursor, which is used to identify a line, or segments of that line, for deletion. Position the cursor on the line and

Select option L.

The selected line flashes, and a menu appears. Then

Select option 1 (Modify points).

This option highlights (in the selected pen color) all segments that form the selected line. The first point of that line is highlighted with arrows. In order to delete the first point and the first line segment,

Select option 2 (Delete).

The delete option highlights the next point and can be repeated indefinitely to delete additional points and line segments. To recover all of the original line, press the escape key. To select another line or to return the cursor to the screen,

Select option 6 (Change complete).

To delete a line segment somewhere after the first point and line segment (for example, the segment at the other end of the line),

Select option 7 (Go to point N).

Enter the appropriate point number from the point range of 1 to n. To delete the other endpoint and the attached line segment, enter the n value and <cr>. This highlights the other endpoint for deletion. As an alternate method, use option 1 (No change), which moves the highlighter through subsequent points. To delete the point and line segment,

Select option 2 (Delete).

Select or respond to "Change complete?" to complete the operation.

C–4. Repairing Line Breaks

To repair breaks, or gaps, in lines, go to the Main Menu, access the Modify Function Menu, select the Item option, and select the line that needs to be extended to fill the gap. The command sequence is

(1) Select option 2 (Delete/Copy/Edit) from the Main Menu.
(2) Select option 3 (Modify).
(3) Select option 1 (Item).
(4) Select option L.
(5) Select option 1 (Modify points).

The "Modify points" option highlights the selected line and the starting point. Line segments can be created only from the highlighted point. If the line segment next to the line break is attached to the starting point, then

Select option 4 (Insert before).

If the point to which a line segment must be added is located at the opposite end of the line from the starting point, then

(1) Select option 1 (No change) or option 7 (Go to point N) to access the other end of the line.
(2) Select option 5 (Insert after).

Options 4 and 5 display a line attached to the point, which can then be pulled by the cursor and attached to another line. Complete the process as follows:

(1) Select option L.
(2) Select option 6 (Change complete).

If the default cursor is not desirable, a simplified cursor can be selected by simultaneously pressing shift and function key 6.

For certain line breaks, TekniCAD responds to options 4 (Insert before) or 5 (Insert after) with the message, "No line item found inside pick aperture." This response is common for a single line that should completely bound a polygon. To correct the line break and thereby close the polygon, the single line must be divided so that the nodes on either side of the line break do not belong to the same line. In the following procedure, this is accomplished by redefining each line segment as a new line. To respond to the screen message,

Select option 6 (Change complete).

Select the line again and

Select option 3 (Explode all segments).

This command "explodes" the line into several lines, each being a line segment of the original line. Normal editing procedures for closing a line break can now be performed.

C–5. Repositioning Points and Line Segments

Use the Replace option in the Modify Function Menu to reposition a point and its associated line segments. Position the cursor on the line segment to be modified, highlight the appropriate point, and move it to a new location. The Replace option permits a replacement location to be identified for the point by use of the yellow button on the puck or by use of the spacebar. The point and attached line segments are then repositioned. From the Main Menu, proceed as follows:

(1) Select option 2 (Delete/Copy/Edit).
(2) Select option 3 (Modify).
(3) Select option 1 (Item).
(4) Select option L.
(5) Select option 1 (Modify points).
(6) Highlight the appropriate point with option 1 or 7.
(7) Select option 3 (Replace).
(8) Select option 6 (Change complete).

For step 7, use the puck to position the cursor in the desired location, then press the yellow button on the puck or press the spacebar to move the point. After all points have been repositioned ("replaced") as needed, or points have been added or deleted, proceed to step 8 (Change complete).

C–6. Tracing Linework

For some maps, even the optimum scan parameters produce a map of poor quality, with many line breaks and extraneous lines. Rather than editing the file, it may be more efficient to trace the linework, using the scanned map as a template. This approach may also be chosen for maps containing dashed lines, which must be converted in digital form to continuous lines so that each dashed line can be identified as a single feature rather than as many separate, and therefore unassociated, short lines. Each line can later be assigned an attribute in ARC/INFO so that it will display as a dashed line.

To trace linework, go to the Main Menu, define a new color for tracing linework, and trace the lines:

(1) Select function key 8.
(2) Select a number to indicate pen color. <cr>
(3) Select option 1 (Geometry).
(4) Select option 1 (Line).
(5) Select option 1 (Free Input/Smooth).
(6) Select option L.

Option L requires that a point be identified. From the point, trace the line segments with the puck while depressing the yellow button. Use the green button on the puck to delete traced line segments that are incorrectly drawn. If the default cursor is not desired for tracing, a simplified cursor can be selected by simultaneously pressing shift and function key 6. To stop the line trace, press <cr>. To terminate the traced line at a point on another line, press l and <cr>. To trace a line precisely, press L instead of the yellow button on the puck to attach new line segments to existing points along the scanned line. All traced line segments are identified in the selected pen color.

To extract the traced coverage from the original linework, use the Blanking option, which saves linework by color. To use it, press the escape key to return to the Main Menu, then

(1) Select option 2 (Delete/Copy/Edit).
(2) Select option 4 (Blank).
(3) Select option 3 (Pen).
(4) Select a number to indicate the pen color for lines to be "blanked" (for example, 1 indicates the default color).
(5) <cr>

The system then requests the user to set the lower left and upper right corners of a box. When the upper right corner is set, all linework of the chosen color will be removed from the box shown on the screen. This procedure may appear to cause a breakup of the traced linework; if so, use a screen refresh such as zooming or redrawing to restore the screen image.

C–7. Saving Edited Linework and Exiting TekniCAD

To save traced linework, return to the Main Menu and do the following:

(1) Select option 7 (Drawing/Symbol).
(2) Select option 1 (Dwng; Save).
(3) Select function key 4 to see options.
(4) Select option 2 (Unblanked items only).
(5) <cr>
(6 <**file name for traced lines**> <cr>
(7) <**file description**> <cr>

The file description is optional; a single <cr> is allowed in its place. Unless otherwise specified, the traced file is saved to a .TDD format file. Specify the .TDA extension (<filename.TDA>) to simplify the procedure for later transfer to the ARC/INFO environment.

To save an edited file without exiting TekniCAD, return to the Main Menu and do the following:

(1) Select option 7 (Drawing/Symbol).
(2) Select option 1 (Dwng; Save).
(3) <**filename**> <cr>
(4) <**file description**> <cr>

Then, another file can be edited:

(1) Select option 2 (Dwng; Restore).
(2) <**filename**> <cr>

To save an edited file and end the TekniCAD session, return to the Main Menu and do the following:

(1) Select option 9 (End Session).
(2) system prompt> Do you want to end this drafting session (Y,N)? <**Y**>
(3) system prompt> Do you want to save it (Y,N)? <**Y**>

C–8. Saving Files to Backup Tape

Files should be saved onto a backup medium, such as a floppy disk or a tape cartridge. Cartridges are preferred because of their higher storage capacity; a 600-ft cartridge can store about 60 MB (megabytes) of data. To write files to tape, move to the root directory above the user's working directory and specify the files to be saved. Check with the system administrator first, as access to the root directory may be restricted. The following dialog shows how to copy the entire directory, individual files, or all files of a certain type (for example, .TDA format) by using the wildcard symbol, an asterisk (*):

system prompt> **cd/** *(move to one directory above the working directory)*
NOTE: The following command will write the entire directory to tape:
system prompt>
cpioout /usr/<directoryname> /&
NOTE: The following command will write individual files to tape:
system prompt> **cpioout /usr/<filename** *(with full pathname)* **> /&**
NOTE: The following command will write files of a specified type to tape:
system prompt> **cpioout /usr/<files of a certain type** *(for example,* **"*.TDA")> /&**
NOTE: The term "cpioout" and the file designation must each be followed by a blank space.
YOUR CPIO TAPE IS COMPLETE
END/DONE
system prompt> **logout**

The tape-writing command can also be executed from within the user's working directory. To do this, issue the command "cpioout" without arguments if all files are to be copied to tape. If a selected subset of files is to be saved, use the commands listed above.

To reload the files from tape, ensure that adequate disk space is available and that files of the same name do not exist on both the workstation disk and the tape. Then, do the following:

system prompt> **cpioload .**
NOTE: The term "cpioload" must be followed by a blank space and a period.

C–9. Deciding Whether to Edit in TekniCAD or ARC/INFO

The TekniCAD editing functions discussed above can also be performed in ARC/INFO. Although some functions may be less efficient in ARC/INFO, certain operations (for example, detecting and correcting line breaks) may be easier in ARC/INFO. The user may perform all editing in either TekniCAD or ARC/INFO or may use both software systems. For our project, we used both. TekniCAD was used for the preliminary edit, to remove extraneous lines, to reposition lines as needed, and to close as many line breaks as possible. Final line inspection and editing were done in ARC/INFO. We had access to, and experience on, both systems. Other users may not. When designing the editing procedures for a map, the user must consider availability of personnel, their level of expertise on the two systems, and the availability of equipment. There are two advantages to performing all editing in ARC/INFO: first, most users are familiar with it, and, second, most users have ready access to it. The TekniCAD system is relatively unfamiliar to many people. Perhaps more significantly, the Tektronix workstation is configured for only a single user, which limits access time for every project. Although we consider the TekniCAD editor to be a useful tool, for many projects, the cost- and time-efficient procedure may be to scan maps with TekScan, inspect them in TekniCAD, and send the unedited data to ARC/INFO for line editing.

D. Transferring the Map Data to the ARC/INFO Environment

The map files, in either unedited or edited form, must next be transferred to a computer that contains ARC/INFO software. We used ARC/INFO on the Reston, Va., GIS laboratory's Prime computer. We transmitted files electronically from the Tektronix scanning workstation to the Prime computer via ftp (using the Ethernet cable) or Kermit software. Ethernet transmits the data much faster and may, therefore, be the preferred course. Using Ethernet and ftp software, the procedure is as follows:

system prompt> **ftp <computer call letters** *(for example,* **qvarsf)>**
username ( ): **<user's ID on the destination computer>**
Password: **<user's password on the destination computer>**
NOTE: The user is now logged onto the destination computer and is positioned in the user's top-level directory. The scanned files will be transmitted here unless a different destination directory is chosen, as follows:
ftp: **cd <full pathname for destination directory** *(for example,* **user>maps)>**
NOTE: If desired, enter the following command to list the directory's contents.
ftp: **ls**
NOTE: Use the following command to transmit .TDA-format files, one at a time:
ftp: **put <filename1>.TDA**
ftp: **put <filename2>.TDA**
. . . . . *.etc.* . . . . . .
ftp: **quit**

For large files (for example, those containing 30 MB), the time needed to transfer the data can be as long as several hours. For such a file, it may be preferable to log onto the Prime computer from another terminal and use an adaptation of the above procedure for data transfer. After invoking ftp on the computer, log onto the Tektronix scanning workstation from the remote terminal, attach to the correct directory on the Tektronix with the cd (change directory) command, and "get" rather than "put" the files. Files will then be copied from the Tektronix onto the computer.

After the files are transferred, the map data reside as Tektronix .TDA-format files in a directory on the Prime computer. These files must be converted to ARC/INFO format. We use a conversion routine written by one of the

authors (Lanfear). This user-created ARC/INFO CPL (command procedure language) routine reads the Tektronix-format input file, converts the file to an ARC/INFO line coverage via ARC's GENERATE command, and builds line topology with the "BUILD <coverage> LINE" command. A coverage is ARC/INFO terminology for a map data file in ARC/INFO format. Before beginning the data conversion, the CPL queries whether the file has been edited in TekniCAD or merely scanned. Unedited files have a slightly different format than TekniCAD-edited files, and the CPL is designed to read both types. Since our method was established, system software has been written that permits conversion of TekniCAD files to ARC/INFO coverages via the IGES (Initial Graphics Exchange Specification) format (T.T. Fitzgibbon, USGS, oral commun., 1990). TekniCAD files are converted to IGES-format files on the Tektronix workstation by using the TCADIGES command. These files are then converted to ARC/INFO coverages with the IGESARC command.

To convert a file to ARC/INFO format, log onto the Prime computer and go to the directory containing the file. If the .TDA or IGES file was transmitted into the user's upper level directory, and if the user would prefer that the map data reside in a subdirectory, then create a subdirectory and copy the .TDA or IGES file:

OK, **CREATE** <**subdirectory**>
OK, **DOWN** <**subdirectory**>
OK, **COPY** <**filename.TDA** *(with full pathname)* >

To invoke Lanfear's conversion CPL, do the following:

OK, **R KJL1>UTILITY>TEK>CONVERT-TEK.CPL**
INPUT FILE NAME: <**filename.TDA**>
OUTPUT COVER NAME: <**newfilename**>
Has the file been edited on the scanner? <**YES** or **NO**>
NOTE: After this response, the computer issues processing statements that require no response.
Arc:

Reading large files and converting them to ARC/INFO coverages can be a lengthy operation. Therefore, for large files, this routine should be executed in batch mode.

The newly generated ARC/INFO coverage exists as a subdirectory named "newfilename." That subdirectory contains several ARC and INFO files that need not be directly accessed by the user. For most ARC/INFO users, the coverage is treated as a file, not a subdirectory, and is accessed and manipulated from the directory above. It is common practice for the directory within which a coverage (subdirectory) resides to contain two or more coverages that are related by geography or topic.

E. Preparing ARC/INFO Coverages for Editing

As discussed above, our method was tested on a map having four overlays, or separates. These separates were each processed into an ARC/INFO coverage. Before these coverages could be edited, they needed to be converted to a map projection and then registered to each other. The procedure is described below.

E–1. Initiating ARC/INFO and Describing the Display Device

We initiated ARC/INFO from the PRIMOS operating system. Much of our final method testing was done with ARC/INFO version 5.0.1; however, the following procedures should be fully applicable with earlier (ARC 4.0 level) software revisions as well. When the user invokes ARC/INFO, certain characteristics of the terminal or workstation may be specified. Although this information is most critical to the graphics subroutines of ARC/INFO (for example, ARCEDIT), the most convenient time to supply this information may be when ARC/INFO is invoked, not when ARCEDIT or ARCPLOT is invoked. To save time, the sequence of commands listed below can be programmed to a function key (see the operator's manual for the terminal for details). The DISPLAY parameter specifies the type of graphics terminal. The TERMINAL parameter sets terminal characteristics for dialog display and pulldown menus. The method of selecting pulldown menu options (for example, by cursor or mouse) must be specified after the TERMINAL command unless the default device (cursor) will be used. To speed editing in ARCEDIT, and especially if pulldown menus are to be used, a mouse is preferred to the cursor. The "device #" is the terminal's model number (for example, "4207" for a Tektronix 4207).

OK, **ARC**
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All Rights Reserved Worldwide
ARC Version 5.0.1
Arc: **DISPLAY** <**device #**>
Example: **DISPLAY 4207**
Arc: **&TERMINAL** <**device #**> **&**<**input device** (*for example,* **MOUSE**)>
Example: **&TERMINAL 4207 &MOUSE**

E–2. Copying Coverages

Usually, the new coverages should be stored and edited in a directory that contains only coverages related by geography or topic. If the .TDA files were not transmitted into such a directory prior to conversion to ARC/INFO coverages, create a new directory in PRIMOS, enter that directory, invoke ARC, and copy the new coverages to the directory as follows:

OK, **CREATE** <**subdirectory**>
OK, **DOWN** <**subdirectory**>
OK, **ARC**
Arc: **COPY** <**coverage** *(with full pathname)*>
<**new name for coverage** *(if original coverage name is acceptable, press* <**cr**> instead)>

If coverages (and their associated INFO directory) have been copied into the subdirectory without using the COPY command in ARC/INFO, for example by using magnetic tape or by copying the entire directory with the COPY command at the PRIMOS level, then pointers to the associated INFO files (for example, .AAT, .TIC) must be reset as follows:

Arc: **EXTERNAL** <**coverage**>
. . . . . *or*. . . . . .
Arc: **EXTERNALALL** *(corrects the INFO file pointers for all coverages in the working directory)*

This procedure must be done before the coverages are edited and before INFO files are viewed and modified, because failure to do so results in a damaged coverage that may be very difficult to recover.

E–3. Adding Latitude-Longitude Tic Marks to Each Coverage

Each map separate that is scanned should contain latitude-longitude intersection marks that can be converted into ARC/INFO tics. These tics are control points that permit coverages to be projected into the proper geographic space. They are essential for establishing precise registration among coverages. The latitude-longitude marks should appear as scanned crosses when the linework is displayed on the screen. In ARCPLOT, inspect each coverage and select the one with the least linework around the crosses and the least distortion of the arcs that form the crosses:

Arc: **ARCPLOT**
ARCPLOT: **MAPE** <**coverage #1**>
ARCPLOT: **ARCS** <**coverage #1**>
ARCPLOT: **CLEAR**
ARCPLOT: **MAPE** <**coverage #2**>
ARCPLOT: **ARCS** <**coverage #2**>
ARCPLOT: **CLEAR**
. . . . . *etc.* . . . . .
ARCPLOT: **QUIT**
Arc:

Next, invoke ARCEDIT. We suggest using an ARCEDIT menu-driven AML (arc macro language) program such as EDIT1.AML, which was written by one of the authors (Lanfear). Using EDIT1.AML, the dialog in ARCEDIT might proceed as follows:

Arc: **&R KJL1>UTILITY>EDIT1.AML**
Procedure EDIT1.AML, Version 3.2
Programmed by Kenneth J. Lanfear, USGS
Invokes ARCEDIT with a menu
User supplied menu (<cr> = default): <**cr**>
Input map name: <**coverage name**>
Output map name (<cr> = input map): <**cr**>
OK to modify the input map? **Y**
Renumber IDs? **N**

If the answer to the "Renumber IDs?" query is "yes," then the program renumbers the coverage ID's and performs an IDEDIT on the attribute tables. For this edit session, this step is not necessary, so answer "no" to the query. Next, the AML loads ARCEDIT, selects "coverage name" as the "EDITCOVER" (the coverage to be edited), and selects "ARCS" as the "EDITFEATURE" (the feature to be edited). A pulldown menu is then displayed.

For most coverages, precise registration with other coverages is desired, and this requires accurate placement of an adequate number of tics. However, to register some maps, it may be sufficient to simply move the four existing tics to new positions that correspond to latitude-longitude intersections (the scanned crosses). Commands to select the four tics, one at a time, and move them are issued from the pulldown menus as follows:

Menu: **SELECT** *Command:* **EDITF TIC**
Menu: **DRAW** *Command:* **DRAWENV...**
DRAWENVIRONMENT: **TIC IDS**
Menu: **DRAW** *Command:* **DRAW**
Menu: **DRAW** *Command:* **Mapextent ***
*NOTE: The Mapextent * command allows a part of the coverage to be displayed in greater detail. Hardware zoom and pan may then be used to enlarge the image for even more accurate tic placement. If precision is not critical, omit the Mapextent * procedure and use only the hardware zoom and pan. See discussion below on the use of Mapextent * and hardware zoom and pan. After viewing an enlargement of a map area containing a tic, select the tic, and move it to the proper location.*
Menu: **SELECT** *Command:* **SELECT**
Menu: **EDIT** *Command:* **MOVE**
NOTE: The MOVE routine will prompt for the location to move the feature from (place mouse or cursor at the tic's current position) and the location to move the feature to (place mouse or cursor over the latitude-longitude intersection).

Moving the four tics may be useful for certain coverages. For example, a scanned cultural base may form a very large coverage that would require a long time (20 minutes or more) to draw to the screen. If this base will be used solely as a background display image and if precise registration is not critical, then satisfactory placement of tics may be done rapidly by using hardware zoom and pan. The four existing tics could be moved, or the old tics could

be deleted and new tics added to match the tics in coverages with which the base will be displayed. In either case, the ID number for each tic must match that for tics in corresponding locations in the other coverages (see additional discussion on this matter below).

Although the above procedure has value in certain applications, we do not recommend it for coverages where precise registration is important. For most applications, we recommend that the user begin by deleting the coverage's four existing tics because the latitude and longitude of these tics cannot be determined; unless their locations can be precisely defined in decimal degrees, they cannot be used to project the coverage. New tics should then be added as outlined below. Commands to select the four existing tics and delete them are issued from the pulldown menus as follows:

Menu: **SELECT** *Command:* **EDITF TIC**
Menu: **SELECT** *Command:* **SELECT ALL**
Menu: **EDIT** *Command:* **DELETE**

Add new tics to the coverage at the latitude-longitude intersections. Remember, the lines that appear at those intersections are arcs, not tic marks; they cannot be used as tic marks in the map projection procedure that will follow, and eventually they should be deleted from the coverage. Add the tics in a systematic manner, perhaps moving from the upper left corner of the coverage to the lower right corner. We recommend using 8 to 12 tics. The tics and their ID numbers must be the same for each coverage, and we suggest recording, on paper, the location and ID number of each tic. In order to more precisely locate the position of each tic, use either the terminal's hardware zoom and pan or ARC/INFO's MAPEXTENT command. We suggest viewing an enlargement of part of the coverage by using MAPEXTENT *, then using hardware zoom and pan to greatly enlarge the area containing a latitude-longitude intersection. This procedure will place the tic more accurately than would using hardware zoom and pan alone.

Menu: **DRAW** *Command:* **DRAWENV...**
DRAWENVIRONMENT: **TIC IDS**
Menu: **DRAW** *Command:* **DRAW**
Menu: **DRAW** *Command:* **Mapextent ***
*NOTE: The MAPEXTENT * command in this AML also causes the selected area to be drawn and eliminates the need to issue another DRAW command.*
Menu: **EDIT** *Command:* **ADD**
NOTE: The system will then display the ADD Menu:

```
1) Add Tic        3) New User-ID        5) Delete last tic
6) New symbol  7) Autoincrement OFF  8) Autoincrement ON
9) Quit
(Tic) User-ID:  5 Coordinate =
```

Although the four preexisting tics have been deleted, the system will nevertheless add tics beginning with tic 5. In order for tics to be numbered sequentially beginning with 1, select ADD Menu option 3 (New User-ID). The EDIT1.AML now requires the user to select "ARCEDIT command" from the SYS Menu and to input the desired tic ID number after the "ARCEDIT:" prompt. This procedure must be followed for the first four tics; thereafter, tics will be correctly numbered by the system.

After adding tics to the intersections within the redefined Mapextent, use MAPEXTENT LAST (an EDIT1.AML choice) or MAPEXTENT DEFAULT to return to the mapextent that shows the entire coverage. Then view an enlargement of another area by using MAPEXTENT *. After all tics have been added, inspect the tics and save the edited coverage:

Menu: **DRAW** *Command:* **Mapextent last** (*or* **DEFAULT**)
Menu: **SYS** *Command:* **Save and QUIT**

Add tics to the remaining coverages and ensure that tic locations and their ID numbers correspond among all coverages. For some coverages, linework may interfere with, or obscure, certain latitude-longitude intersections. Rather than guessing at the proper location, do not add a tic there. For the next tic to be added to that coverage, select option 3 (New User-ID) from the ADD Menu to advance to the appropriate ID number. It is not essential that all coverages have the same number of tics, but each tic ID number must correspond to tics in the same geographic position in all coverages.

E–4. Converting Tic Coordinates from Scanner Units to Latitude and Longitude

The coordinates of each tic in a coverage must be converted from scanner units to latitude and longitude so that all coverages can later be projected and transformed into the proper geographic space. Before conversion, a new, empty coverage (that is, one that contains no point, arc, or polygon information) must be created by using the tic information of one of the map coverages. The first coverage processed in section E–3 has the best placement and most complete array of tics and should be used as that map coverage (it is the "firstcoverage" in the dialog section below). Then, the INFO software is used to convert tic coordinates for the empty coverage from scanner units to latitude and longitude.

```
Arc: CREATE <emptycoverage>
     <firstcoverage>
Arc: INFO
  INFO  EXCHANGE  CALL
WED, DEC 20, 1989
INFO  9.42  12/  1/86  52.74.63*
COPYRIGHT 1986 HENCO SOFTWARE, INC.
PROPRIETARY TO HENCO SOFTWARE, INC.
```

```
US GOVT AGENCIES SEE USAGE RESTRICTIONS
   IN HELP FILES (HELP RESTRICTIONS)
ENTER USER NAME> ARC
```

NOTE: INFO will not accept entry of lowercase letters, which are used here to distinguish command variables, such as coverage names, from commands, as discussed in "About the User's Manual Format and Syntax."

```
ENTER COMMAND>  SEL
   <emptycoverage>.TIC
ENTER COMMAND>  IT or LI
```

NOTE: "IT" is the abbreviation for "ITEMS," which lists the names and formats of items in the .TIC file. For a .TIC file, the items are IDTIC, XTIC, and YTIC. XTIC = Longitude (negative values in the Western Hemisphere), and YTIC = Latitude (positive values in the Northern Hemisphere). "LI" is the abbreviation for "LIST"; it lists the internal record number ("$RECNO"), IDTIC, XTIC, and YTIC value for each tic.

```
ENTER COMMAND>  UPDATE BY IDTIC
IDTIC?>  <tic number (for example, 1)>

            1
IDTIC       = 1
XTIC        = 475.2
YTIC        = 329.6
?>  XTIC    = -84.0
?>  YTIC    = 46.0
?>  <cr>
IDTIC?>
```

After converting all tic coordinates, press <cr> after the IDTIC?> prompt to exit to the ENTER COMMAND> prompt. Review the tic file with the LI command, then exit INFO as follows:

```
ENTER COMMAND>  Q
ENTER USER NAME>  STOP
Arc:
```

E–5. Selecting a Map Projection and Projecting the Empty Coverage

Determine the map projection of the scanned copy and project the empty coverage according to the following example. The tic positions, presently in latitude and longitude coordinates, will be converted to the specified unit of measure and arranged in the selected coordinate system and projection. The ".prj" extension is not mandatory; it is used here solely to identify the projected coverage.

```
Arc:  PROJECT  COVER  <emptycoverage>
   <empty.prj>
Please define the input and output map projections.
Use INPUT to define the input projection, OUTPUT to
define the output projection, and END to finish.

Project:  INPUT
Project:  PROJ  GEOGRAPHIC
Project:  UNITS  DD (for decimal degrees)
Project:  PARAMETERS
Project:  OUTPUT
Project:  PROJ  LAMBERT
Project:  UNITS  METERS
Project:  PARAMETERS
1st standard parallel:  46  30  00
2nd standard parallel:  48  30  00
central meridian:  -107  30  00
latitude of projection's origin:  47  30  00
false easting (meters):  0
false northing (meters):  0
Project:  END
Arc:
```

E–6. Transforming Coverages to Map Projection Coordinates

At this stage, each coverage containing map data is unprojected, and all map information is in x- and y-coordinates recorded by the scanner in either millimeters or inches. The TRANSFORM function converts the map information to the map units and map projection specified in the previous step (section E–5) by using the tics in the empty coverage "empty.prj" as a template. For the TRANSFORM function to operate successfully, each coverage to be transformed must contain at least some (and as many as possible) of the tics that are contained in the "empty.prj" coverage. Also, tic ID numbers and locations of tics must agree between coverages. Before transforming the coverages, create one copy of "empty.prj" for each coverage to be transformed. Then, the TRANSFORM function will place a transformed copy of a coverage's map data into the empty coverage that has been copied from "empty.prj."

Commonly, each copy of "empty.prj" is named as some variation of the name of the original, unprojected map coverages. For example, if an unprojected coverage is named "GEOLOGY" (represented as "coverage#1" in the following dialog), then the copy of "empty.prj" could be named "GEOLOGY2" (represented as "coverage#1.prj" in the following dialog). Successive modifications of the coverage, such as those made after line editing or polygon tagging, can be denoted by higher numbered coverages (for example, "GEOLOGY3," "GEOLOGY4").

Copy the empty coverage and transform the map data as follows:

```
Arc:  COPY  <empty.prj>  <coverage#1.prj>
Arc:  COPY  <empty.prj>  <coverage#2.prj>
. . .do this for each of the coverages to be transformed. . .
Arc:  TRANSFORM  <coverage#1>
   coverage#1.prj>
Transforming coordinates for coverage
   COVERAGE#1
NOTE:  Transformation data will appear here.
Arc:
```

The displayed transformation data include values for the RMS (root-mean-square) error, which is a measure of the degree of fit between the tics of the input coverage (coverage#1) and the tics of the empty coverage (coverage#1.prj). If the RMS error is high, the map data will be somewhat distorted by the transformation. Common sources of a high RMS error are tics that are poorly located on the source materials, tics that were poorly located using ARCEDIT's ADD command, or mismatches of tic ID numbers. If tic ID numbers are mismatched, edit them in INFO by using the UPDATE command, delete the ".prj" coverage (with the ARC KILL command), and execute the transformation again. The range of acceptable RMS values will vary depending on the map scale and accuracy of the map data; therefore, as recommended in the ARC/INFO manual, a guideline for acceptable RMS values may be established for a given map project.

E–7. Delineating the Boundaries of Maps Lacking Neatlines

Maps are commonly enclosed within a neatline, which is a carefully positioned map outline that may or may not be defined by lines of latitude and longitude. Some scanned maps do not have neatlines, or they have neatlines that are improperly positioned or of inadequate line quality. Neatlines or some sort of bounding lines must be added to the map's arc information if the map is to have polygon information. This section describes several techniques and commands that are widely applicable to processing coverages; here, they are used to create a neatline, truncate or clip the map's line coverage at the neatline, add the neatline to the line coverage, and edit the arcs to establish the desired arc-node topology.

To create a new coverage containing the neatline, the GENERATE command may be used with either the GRID or the LINE subcommand. The GRID subcommand is particularly useful for generating a latitude-longitude grid overlay for a coverage, and GRID can be used to create a neatline, although that procedure is not discussed here. A simple, straightforward method for generating a neatline is shown below. This method creates a neatline whose lines, defined by latitude and longitude, outline a quadrangle. Note the coordinates of the quadrangle corners, invoke GENERATE with the LINE subcommand, and enter starting and ending coordinates for the four lines that form the neatline:

```
Arc: GENERATE <coverage (for example, neatline)>
Generate: LINE
NOTE: If needed, online help is available for the specified command (for example, HELP LINE).
Enter Lines.
Terminate Line by entering END at X,Y: prompt.
Terminate input by entering END at ID: prompt.
NOTE: The system will prompt for a line ID number that will be associated with the line coordinates entered after the X,Y: prompts. For the first X,Y: prompt, enter the coordinate pair for a quadrangle corner; X = Longitude (negative values in the Western Hemisphere) and Y = Latitude (positive values in the Northern Hemisphere). For the second X,Y: prompt, enter another coordinate pair to define a side of the neatline. From these two coordinate pairs, GENERATE can create a line that forms one side of the neatline. For the third X,Y: prompt, enter END to receive another ID: prompt. Proceed as described above until the four sides of the neatline have been defined by pairs of x- and y-coordinates.
ID: <line number>
X,Y: <starting coordinate pair (for example, -96,40)>
X,Y: <ending coordinate pair (for example, -96,44)>
X,Y: END
ID: <etc.>
ID: END
Generate: QUIT
Externalling BND and TIC...
Arc:
```

This procedure results in a box, whose four sides are composed of arcs described only by starting and ending coordinate pairs. Because it is described by geographic coordinates, this box is not yet a usable neatline; it must be converted to the projection used for the map coverages. However, before the neatline is projected, its arcs may need to be modified. Neatlines for the Quaternary sediments map define 1:1,000,000-scale quadrangles in the Lambert projection system. At this scale and projection, lines of latitude are curved. To obtain a curved line when the neatline is projected, additional coordinates (vertices) must be added to the arcs of latitude. The process of adding vertices to an arc is called densifying the arc. Because only the lines of latitude are curved for this map, only they must be densified. They can be selected in ARCEDIT and densified interactively with the DENSIFY command, or all four arcs of the neatline can be densified automatically at the Arc level with the DENSIFYARC command. The following example uses the ARCEDIT approach. Although the EDIT1.AML menu commands are not given in the example, this procedure is facilitated by the EDIT1.AML program or other pulldown menu programs.

```
ARCEDIT: EDITCOVERAGE <neatline>
ARCEDIT: EDITFEATURE ARC
NOTE: Draw the neatline coverage by issuing DRAWENVIRONMENT ARC and DRAW.
ARCEDIT: SELECT MANY
NOTE: Select the top and bottom arcs (the lines of latitude).
ARCEDIT: DENSIFY <distance>
```

NOTE: The distance specified in the DENSIFY command refers to distance between added vertices, in coverage units. Because the neatline is described in geographic coordinates, the coverage unit is decimal degrees. For our maps, a distance of .05 might be appropriate. To select appropriate distance values, the vertices can be drawn by issuing the SETDRAWSYMBOL 2 command to change drawing colors and VERTEX DRAW. If vertex spacing is inappropriate, issue the OOPS command three times to undo the VERTEX DRAW, SETDRAWSYMBOL 2, and DENSIFY commands. See section F–1 for more discussion of the OOPS command. Select the appropriate distance by trial and error.

ARCEDIT: **SAVE**
ARCEDIT: **QUIT**

Next, project the neatline and build polygon topology in preparation for integrating the neatline into the map coverage. After the topology is built, the CLIP command is issued to remove arc segments in the map coverage that lie outside the neatline. In the following example, "neatline" is the unprojected neatline, and "neatline2" is the projected neatline.

Arc: **PROJECT COVER** <**neatline**> <**neatline2**>
NOTE: Refer to the discussion of projection commands in section E–5.
Arc: **BUILD** <**neatline2**>
NOTE: Use the default POLY option for the BUILD command, which need not be specified after "neatline2."
Arc: **CLIP** <**input map coverage**> <**neatline2**> <**output (the "clipped") map coverage**> **LINE**
NOTE: We used the default fuzzy tolerance in the CLIP command. If a fuzzy tolerance is specified, enter it after the LINE argument.

The CLIP command truncates arcs at the edge of data in the clip coverage ("neatline2" in the above example), but it does not add the neatline to the map coverage. The neatline must be added to the coverage in ARCEDIT, and proper arc-node topology must be established. The CLIP command does not cause the position of the truncated arc to be perfectly matched to the neatline position in the clip coverage. Therefore, if the clip coverage is later added to the map coverage, truncated arcs may fall short of, or extend beyond (overshoot), the neatline. Because the truncated end of such an arc is not connected to another arc, it is referred to as a dangling arc. These topological errors should be corrected in ARCEDIT and in Arc. The ARCEDIT EXTEND command identifies a truncated arc, searches within a specified distance, and, if another arc is found, extends the truncated arc to meet that arc. Before executing the EXTEND command, the user should remove dangling arcs in the coverage's interior area so that the EXTEND command does not create undesirable arc-node topology within the map coverage. For example, the latitude-longitude intersections, or crosses, may consist of four dangling arcs, each joined to the others in the center of the cross. It may be advisable to remove these crosses (see step 1 of section F–2) before issuing the EXTEND command. However, the crosses probably will not be extended to other nearby arcs because the distance argument to the EXTEND command will be set at a very short distance that should not cause most dangling arcs to be connected to another arc. In the following dialog section, the neatline is added to the map coverage, and the desired arc-node topology is established with the EXTEND and CLEAN commands:

ARCEDIT: **EDITCOVERAGE** <**map coverage**>
ARCEDIT: **GET** <**neatline2**>
NOTE: Draw the map coverage, and select and delete (perhaps by using SELECT BOX) the latitude-longitude crosses and other dangling arcs in interior parts of the map coverage.
ARCEDIT: **GRAPHICS OFF**
ARCEDIT: **EDITFEATURE ARC**
ARCEDIT: **SELECT ALL**
ARCEDIT: **EXTEND BOTH** <**distance**>
NOTE: The distance is in coverage units. Select a very small distance. For our coverages, we used a distance of about 10 m. After the command has executed, the number of dangling arcs remaining can be viewed by turning GRAPHICS ON and drawing the coverage with DRAWENVIRONMENT NODE DANGLE. The EXTEND command may be reissued with a larger distance to check if more dangling nodes exist inside the neatline. Because dangling nodes can also be attached to arc overshoots, the EXTEND command will not resolve all dangling arcs.
ARCEDIT: **SAVE**
ARCEDIT: **QUIT**
NOTE: The following command reestablishes proper arc-node topology and integrates the neatline into the map coverage ("output map coverage" in the following example).
Arc: **CLEAN** <**input map coverage**> <**output map coverage**> **# # LINE**
NOTE: We used the default fuzzy tolerance in this example, although for some maps, the default is not appropriate; see section F–2. As will be noted by comparison of the preceding command line with examples given in the ARC/INFO manual, no input is required if the default value for an argument is chosen, unless it is followed by an argument for which the default value is not chosen. Then, # must be used to specify the default value. After the coverage has been cleaned, invoke ARCEDIT, inspect the coverage and delete any dangling arcs outside the neatline, and exit

ARCEDIT. If any arcs were deleted, issue the following command:

```
Arc: BUILD <output map coverage> LINE
```

The map coverage is now bounded by a precisely defined neatline and has proper arc-node topology.

E–8. Checking and Adjusting Registration

In ARCEDIT, check the registration of all coverages by selecting an EDITCOVERAGE and drawing the other coverages as BACKCOVERAGES. If all scan copies could be registered to each other, then coverage registration should be precise. In certain cases, however, registration is not acceptable. To correct misregistrations, two techniques may be used: transformation or rubber-sheeting. Transformation is a linear conversion of one coverage's coordinates to another's and is performed in ARC; rubber-sheeting is an interactive method of adjusting a coverage that is commonly done in ARCEDIT. Transformation is commonly used to correct a uniform shift or misregistration, and rubber-sheeting is used to correct more localized distortions and misregistrations of map data.

The transformation technique is easier to implement and is based on coverage tics. Identifiable reference points in one coverage are compared with the same points in another coverage; this comparison is used to determine a least-squares linear transformation for converting all arcs and label points. To transform a coverage, first select the coverage (the target coverage) to which other coverages will be registered. It is prudent to work with copies of the coverages, and so, before proceeding, copy each coverage. In ARCEDIT, delete existing tics in all coverages. For the target coverage and the coverages to be transformed, inspect for features such as uniquely shaped parts of arcs that are shared by the coverages and that should, therefore, occupy identical geographic positions. For example, if both coverages contain the same shoreline, look for distinctive shoreline configurations that are identifiable on both coverages. For identical positions on such features, place a tic and assign the same tic ID number for all coverages. We recommend placing 8 to 12 tics in each coverage to get the best results. When this is done, save each coverage and quit ARCEDIT. Create an empty coverage ("coverage.prj") possessing the tics of the target coverage, and transform the coverage as follows:

```
Arc: CREATE <coverage.prj>
   <targetcoverage>
Arc: TRANSFORM <coverage>
   <coverage.prj>
```

If coverages still do not register properly, adjust the positions of tics and (or) add more tics to "coverage" and "targetcoverage," delete the old "coverage.prj" by using the KILL command, create a new "coverage.prj," and transform "coverage" again.

This technique relies on placement of tics at features common to all coverages. Many coverages do not have enough, or any, common features. Then, there are two choices: offset estimation or rubber-sheeting. If the amount of misregistration, or coverage offset, can be estimated, tics can be placed in the target coverage and then can be placed in the other coverages in locations that are offset by the estimated distance. If TRANSFORM does not produce the desired result, then adjust tics in the transformed coverage until, by trial and error, the transformed and target coverages register.

Rubber-sheeting is somewhat similar to offset estimation, but it is more effectively implemented for some coverages. Rubber-sheeting is more difficult to learn than transformation, but it can be a powerful, interactive tool for salvaging misregistered coverages by using ARCEDIT or a combination of ARCEDIT and ARC. However, because it is a powerful and flexible tool for distorting coverages, it must be used with caution. If rubber-sheeting is not applied carefully and methodically, the effects of the commands can be hard to predict, and a coverage can be distorted in ways not intended by the user.

The need for rubber-sheeting to bring coverages into proper registration may indicate that the scanned map was distorted in some way. This problem is probably most common with non-scale-stable base material such as paper, especially if it has been folded. Also, if the projection of the scanned map has not been correctly determined, distortions that require rubber-sheeting may result upon conversion of the map from its assumed projection into some desired projection in order to match related coverages. Determining the correct projection of the scanned map may eliminate the need for rubber-sheeting.

Some of the commands required for rubber-sheeting are unique and are not listed in EDIT1.AML; therefore, we performed rubber-sheeting by invoking ARCEDIT without the AML. If ARCEDIT is not invoked by EDIT1.AML, and if a mouse will be used to identify the linked features, then COORDINATE MOUSE must be specified. If a cursor must be used for graphic input because a mouse is not available, then magnification using MAPEXTENT * is particularly important to ensure proper placement of the link points. Rubber-sheeting involves the "linking" of features in the target coverage (the SNAPCOVERAGE) and in the coverage to be rubber-sheeted; "free points" are identified on the rubber-sheeted coverage, and corresponding "snap points" are identified on the target coverage. The effects of rubber-sheeting diminish, by a mathematical function, away from linked features. However, the limits of rubber-sheeting can be set with LIMITADJUST BOX. The maximum distance that a feature will be moved should be close to the greatest degree of misregistration between the two

coverages, and it is set with the SNAPPING CLOSEST * command. The ARCEDIT dialog may proceed as shown below. However, the ARC/INFO (volumes 1 and 2) and ARCEDIT user's manuals should be consulted before using this technique, because the following command sequence is but one of many that can be used to rubber-sheet a coverage.

ARCEDIT: **COORDINATE MOUSE**
ARCEDIT: **EDITCOVERAGE** <**coverage**>
ARCEDIT: **BACKCOVERAGE** <**targetcoverage**> <**linecolor** (*for example,* **2**)>
ARCEDIT: **DRAWENVIRONMENT ARC**
ARCEDIT: **BACKENVIRONMENT ARC**
ARCEDIT: **DRAW**
ARCEDIT: **MAPEXTENT** * *(if needed to view an enlargement of an area)*
ARCEDIT: **DRAW** *(if previous step is performed)*
ARCEDIT: **EDITFEATURE LINK**
ARCEDIT: **SNAPCOVERAGE** <**targetcoverage**>
ARCEDIT: **LINKFEATURE ARC ARC**
ARCEDIT: **SNAPPING CLOSEST** *
Enter 2 points defining the distance *(by using the mouse)*
ARCEDIT: **LIMITADJUST BOX**
Define the box *(by using the mouse to identify lower left and upper right corners)*
Limiting box has an area: 23929.370 and a perimeter: 2244.081
Deleting all links falling outside of limiting area...
Adding the perimeter of the limiting area as identity links...
ARCEDIT: **ADD**
- - - - - - - - - - - - - - - Options - - - - - - - - - - - - - - -
1) Free point 2) Snap point 3) Set symbol
9) Quit
Link #111 : *locate free point on editcoverage, press* ***1****, then locate corresponding snap point on target coverage and press* ***2***
Link #112 : *repeat steps in Link #111 for other points*
Link #113 : <**9**>
2 link(s) added to "FULL PATHNAME>COVERAGE"
ARCEDIT: **ADJUST**
Adjusting coverage "FULL PATHNAME>COVERAGE"
Building the adjustment structure from the links for the first pass...
Proximal tolerance set to 79.425...
Generating convex hull...
Building Triangular Irregular Network...
adjusting ARCs...
adjusting LABELs...
adjusting ANNOTATION...
Updating the adjustment structure for the second pass...
adjusting ARCs...
adjusting LABELs...
adjusting ANNOTATION...
ARCEDIT:
NOTE: Display coverages and check for proper registration. If more adjustment is required, see discussion in next paragraph. If registration is acceptable, save the coverage, quit ARCEDIT, and rebuild the coverage's topology:
ARCEDIT: **SAVE**
ARCEDIT: **QUIT**
Arc: **BUILD** <**coverage**> <**POLY** *or* **LINE**>
NOTE: Use the LINE option unless the rubber-sheeting is performed after polygon topology has been built. POLY is the default option; therefore, if a polygon coverage is being rubber-sheeted, then the user does not need to specify an option.

If, after ADJUST is executed, "coverage" does not register to the target coverage, then it can be adjusted further by adding links until the desired results are achieved. However, because of the compounding effects of linking and adjusting, the nature of subsequent adjustments may be difficult to predict. It may, therefore, be easier to use the OOPS command to undo the adjustment. OOPS must be issued twice, first to undo the adjustment, and then to undo the addition of links. New links can then be added, and the coverage can be adjusted. Even so, it is still difficult to predict the changes in line positions caused by linking and adjusting. It may be desirable, therefore, to save the adjusted coverage and display it as a backcoverage for comparison while adding new links either to a copy of the original coverage or to a copy of the adjusted coverage. After rubber-sheeting has been completed, topology should be rebuilt by using the BUILD command.

F. Editing the Coverages in ARCEDIT

F–1. Setting Up an ARCEDIT Session

From the ARC environment, invoke ARCEDIT, preferably by an AML with pulldown menus (for example, EDIT1.AML). Because of the command-intensive nature of ARCEDIT, it is most efficient to select commands and edit a coverage by using a mouse rather than a cursor as the graphic input device. Draw the editcoverage, redefine the Mapextent as needed, and use the hardware zoom and pan to enlarge an area sufficiently for convenient editing. Set the EDITDISTANCE (search tolerance for selecting features) and the SNAPDISTANCE (tolerance for snapping nodes). If the * option is used for these parameters, then the distances can be set interactively on the display screen by defining two points with the cursor or mouse. These parameters are particularly important when arcs are being added or edited. Proceed with the edit session, redefining the Mapextent as needed via the DEFAULT, Last, and * options. During editing, any operations performed that are later regretted (for example, unintentional deletions of data) can be undone by using the OOPS command. Each time the OOPS command is issued, the previous operation is

undone, and the data set is restored to its former condition. If the mistake has been followed by three operations, or transactions, such as feature selections, additions, or deletions, the OOPS command must be issued three times. A record of edit transactions is kept by ARCEDIT, and it can be reviewed with the AUDITTRAIL command and the BRIEF or FULL option. However, certain information issued by ARCEDIT is in binary format and is contained in the AUDITTRAIL file; these binary commands are not readable and may cause problems if the file is listed to a printer.

F–2. Cleaning Up the Linework

Before polygons are built and label points are added, each coverage should be edited to remove unwanted lines (arcs in ARC/INFO), repair any gaps in lines, and adjust the positions of selected lines. Linework that has been fully edited in TekniCAD also must be inspected and edited because some line errors may appear after conversion to ARC/INFO format and map transformation. Editing steps are described below.

(1) Select and delete all arcs that compose the latitude-longitude intersection marks.

(2) Where linework crosses a latitude-longitude intersection mark, the linework will likely be distorted during scanning. After removing the intersection mark, reposition the linework.

(3) Check for line gaps by drawing the coverage with the DRAWENVIRONMENT NODE DANGLE option. Line gaps occur where arcs end in a node that is not shared with another arc (that is, the node "dangles" from the end of an arc). These nodes will be highlighted; then the user can rapidly identify and correct the line gaps with the ADD command.

(4) Check each coverage for the small, extraneous arcs that may be introduced between tightly spaced lines by the scanner or the ARC/INFO GENERATE command. Commonly, linework is also distorted near areas containing these small arcs. Remove these unwanted lines and adjust the positions of lines to be retained.

(5) If a coverage was extensively edited in TekniCAD, many arcs may exist where a single, longer arc could suffice. These arcs commonly formed when the TekniCAD explode command was used to close polygons originally composed of a single line (see section C–4). The Arc UNSPLIT command provides the fewest arcs that can describe the coverage. See section F–8 for details on the UNSPLIT command. This command can significantly reduce file size and time needed to redraw a coverage on the screen. For one of our coverages, 3,071 arcs were unsplit into 1,099 arcs, and file size was reduced by one-third.

(6) If previous steps (in sections E and F) have been completed, coverages should be registered. However, check again for proper registration with related coverages, especially in areas of tightly spaced linework. To display the related coverages, use the BACKCOVERAGE command with the symbol option to specify a different color. Reshape arcs or delete and replace arcs as needed, using commands including SELECT, ADD, DELETE, SPLIT, MOVE, VERTEX DRAW, VERTEX MOVE, VERTEX ADD, and VERTEX DELETE.

(7) Review all coverages for errors in line quality and registration. Save the editcoverage and quit ARCEDIT.

(8) BUILD all coverages with the LINE option:

```
Arc: BUILD <coverage> LINE
```

If the BUILD operation fails because some intersecting arcs were created during the editing session, correct the problem, as discussed in section F–7, and rebuild the coverage. If the BUILD operation continues to fail, topology can be established with the CLEAN command, which can correct errors in linework. The CLEAN command is a powerful tool that redefines the geographic position of all features. Therefore, it should not be used routinely to rebuild topology. Once topology has been established, use the BUILD command instead whenever possible. The only argument required by CLEAN is the coverage to be cleaned. The other arguments have default values. The fuzzy tolerance argument must be carefully considered, because it is a measure of map resolution and defines the extent to which arcs can be moved during the "cleaning" process. If the fuzzy tolerance is set too high, then arcs will become misplaced; if the tolerance is set too low, then the command will require an excessive amount of computer time. For coverages similar in size and scale to the quadrangles making up the Quaternary sediments map, the ARC/INFO rule for calculating the default fuzzy tolerance is (width of the BND)/10,000, which is roughly 5 m. Considering that the map was compiled, and will be published, at 1:1,000,000 scale, we judged this level of resolution to be unnecessarily high. We selected a 50-m tolerance as a compromise between resolution and computer processing time.

F–3. Ordering the ID Numbers in the Attribute Tables

When the user edits, adds, or deletes arcs or label points in ARCEDIT, ID numbers in the coverage's attribute tables are modified. When the user exits from ARCEDIT, the coverage's topology must be rebuilt. If the coverage requires any further editing or processing with INFO, potentially fatal problems may arise because the ID numbers in the attribute tables no longer match ID numbers in the coverage's coordinate files. Most coverages require, at

some time, some form of INFO processing such as recalculation of item values. We, therefore, advise the user to be cautious and avoid a potentially unusable data base by performing the following procedure after editing and rebuilding a coverage. This procedure recalculates the ID numbers in the arc and polygon attribute tables so that they correspond to the ARC/INFO internal number for each arc or label feature. ARC/INFO internal numbers are designated as "<COVERAGE>#". The IDEDIT command matches features in the coordinate files to the attribute tables. It also informs the user if more than one polygon label point remained in a given polygon when the previous edit session ended; this information can also be obtained by the LABELERRORS command. Note that below, and for any INFO commands, correct syntax is essential; uppercase letters must be used, and all operators (for example, =, +) must be surrounded by blank spaces.

ARCEDIT: *During the edit session, arcs and label points are moved, added, or deleted. After editing is done, SAVE the coverage and QUIT ARCEDIT.*
Arc: **BUILD** <**coverage**>
NOTE: If the coverage is rebuilt successfully, perform the following steps. If errors exist in the coverage that prevent it from being rebuilt, reenter ARCEDIT. If EDIT1.AML is being used, the NO option for Renumber IDs? must be selected. Correct the error(s) (see discussion in section F–7), and try to BUILD the coverage again. If the BUILD command repeatedly fails to rebuild the topology, use of the CLEAN command must be considered, as discussed in section F–2.
Arc: **INFO**
ENTER COMMAND> **SEL** <**coverage**>**.PAT**
(if it exists)
ENTER COMMAND> **CALC** <**coverage**>**-ID** = <**coverage**>**#** – **1**
ENTER COMMAND> **SEL** <**coverage**>**.AAT**
(if it exists)
ENTER COMMAND> **CALC** <**coverage**>**-ID** = <**coverage**>**#**
ENTER COMMAND> **Q**
ENTER USER NAME> **STOP**
Arc: **IDEDIT** <**coverage**> **POLY**
Arc: **IDEDIT** <**coverage**> **LINE**

This procedure is contained as an option (Renumber IDs?) in the setup part of EDIT1.AML. Users might also find it helpful to create a separate AML to perform the INFO update and IDEDIT procedure. Its use on a coverage whenever the user is unsure of the correspondence of records among the coverage's various ARC/INFO files may prevent serious problems.

F–4. Adding Polygon Information to Each Coverage

A coverage's linework must be edited to final form, or to some acceptable interim level, before proceeding further. If errors such as line gaps and extraneous lines that form polygons have not been corrected, then the process of adding polygon attribute information will be slowed.

Before polygon attribute information is added, polygon topology must be built, and an item or items must be added to the newly created polygon attribute table (.PAT). The additional item(s) are needed to differentiate the polygons (for example, by geologic unit or lithology). For each new item, a format must be specified. We commonly use a format of "4 5 B" for items identifying the type of polygon or the hardware shadeset color to be assigned to a polygon. Character information can also be contained in items so specified. If output to DLG[1] (digital line graph) format is desired, items must be named "MINOR1", "MINOR2", and so on, and must be accompanied by a major item (for example, MAJOR1, MINOR1). The minor items must have the format "6 6 I", and the major items must have the format "3 3 I". If DLG output is needed, but items that identify polygon-type are not properly named and formatted, those item values can be placed in the properly formatted item by using the CALCULATE command in INFO. See section G–4 for discussion of the ARC-to-DLG conversion.

Label points may then be added to the coverage interactively or by a single command. Although we chose not to use the interactive method, it may be preferable for certain maps. To add label points interactively, the user may lay the map on a digitizing table or view the map on the terminal screen and add label points one at a time, assigning item values during the session or after all labels have been added. This technique allows the user to select the location of the label point, thereby minimizing the chances that blank polygons or multiple label points in a polygon will be produced upon conversion to Scitex format. The shape of polygons and placement of label points may have some bearing on whether, upon output to the Scitex, label points will remain associated with the proper polygon. Polygons that are long, narrow, and curved may be especially vulnerable to having their labels disassociated from them.

The choice of techniques is largely a matter of personal preference and the distribution of map units. We chose the automated approach, which, for our data set, yielded few problems on the Scitex. The automated approach uses the CREATELABELS command. The last argument to this command, id-base, specifies the initial <COVERAGE>-ID number. If 0 (zero) is chosen, as in the example below, new labels will be added to all polygons, and the <COVERAGE>-ID will equal the polygon's internal number minus one. Add the label points as follows:

Arc: **BUILD** <**coverage**> *(with the default POLY option)*

[1]Information on DLG's is available from the USGS, 510 National Center, Reston, VA 22092.

NOTE: For large coverages, the BUILD operation with the default POLY option may take a long time to execute. Therefore, it would be appropriate to perform the BUILD in batch mode.

Arc: **ADDITEM <coverage>.PAT <coverage>.PAT <item** *(for example,* **"GEOLOGY")> <format** *(for example,* **4 5 B** *or* **6 6 I)>**

Arc: **CREATELABELS <coverage> 0**

For convenience, several items of the same format can be specified within a single argument in ADDITEM. For example, if each polygon in coverage MT must be tagged with MINOR1 and MINOR2 codes of the format 6 6 I, as required for DLG output, the command could appear as follows:

Arc: **ADDITEM MT.PAT MT.PAT (! MINOR1,MINOR2 !) 6 6 I**

Next, invoke ARCEDIT and draw the coverage after specifying "DRAWENVIRONMENT ARC, LABEL." Use hardware zoom and pan to enlarge a part of the coverage; the degree of magnification must be a compromise between reducing the number of label points to a manageable number and retaining enough of the coverage to allow ready identification of polygons. Because features will not be added or removed, the MAPEXTENT * zoom technique need not be used.

For each field of view, tag all the polygons for each map unit. The TAG Menu in the EDIT1.AML may speed this process. It prompts for an item name, the value to assign to that item, and a DRAWSYMBOL color. Each label point that should have that item value is selected interactively and tagged. To follow this procedure, invoke EDIT1.AML, select DRAWENVIRONMENT LABEL and DRAW commands from the DRAW Menu, select the EDITF LABEL command from the SELECT Menu, then select the "Tag with number" command from the TAG Menu. This last command invokes the following dialog:

Item name (CR = last item assigned): <**item name** *(for example,* **MINOR1**)>
Value to assign: <**value** *(for example,* **101**)>
Color number (CR = current drawsymbol): <**drawsymbol #**>

1 = Select 2 = Next 3 = Tag 9 = Exit

The Select, Next, Tag, and Exit options allow the user to interactively select and tag each polygon of a given map unit, as defined by the chosen item name.

For character information, use the "Tag with character" command, or issue the MOVEITEM command after selecting "ARCEDIT command:" from the Sys Menu. The characters must be enclosed by single quotation marks. To assign character information to a selected label point, issue the MOVEITEM command as follows:

MOVEITEM <'character information' *(for example,* **'qal')> TO <item name>**

Character information is often entered incorrectly. As a result, several different misspellings of a unit identifier such as a geologic formation name can occur. We prefer the simplicity inherent in using numeric data to represent character information. Label points are more easily tagged, and the chances of mislabeling are somewhat reduced. A table relating the character information to unique numbers is needed by the user when tagging the label points. Character information will not be discussed further in this report.

One map unit at a time, all label points within the field of view should be tagged. When all label points have been tagged (and colored if the TAG subroutine of EDIT1.AML is being used), use hardware pan to view another part of the map. Proceed systematically across the map. When tagging and coloring are completed, redraw the coverage. Redrawing will cause all colored label points to revert to the default (white). Check for untagged polygons by selecting for label points with the default value; untagged polygons will retain the default value of 0 (zero). Draw any selected label points in another color by using the SETDRAWSYMBOL and DRAWSELECT commands, then tag them appropriately.

Several techniques can be used for tagging polygons, and selecting the most efficient technique requires some planning. The TAG subroutine method is not the most efficient one for all coverages. If a map has many polygons but only a few map units, the preferred technique may be to select all the label points, calculate them to the value of the most common map unit, and then interactively retag those polygons that should have different values. Conversely, some maps contain a large number of map units (for example, 20 or more), and no single map unit accounts for a predominant number of the polygons. For such a coverage, a field of view may contain only one or two label points for any given map unit; it may, therefore, be faster to interactively select each label point and calculate the proper item value than to use the TAG menu. For other coverages, many label points of the same map unit may be clustered in part of the map. The efficient tagging method there may be to use the SELECT BOX command to select all label points within an area, calculate them all to the value for the most common map unit, and then interactively select and recalculate those label points that should have different item values.

F–5. Assigning Item Values to Arcs on the basis of Polygon Item Values

In many coverages, arcs must be assigned attribute information that is dependent on polygon information (for example, contour values or type of geologic contact). These arc items can be tagged automatically by relating the .AAT

to the .PAT and by selecting and calculating item values as shown in the two examples below.

```
Arc: INFO
ENTER COMMAND> SEL <coverage>.AAT
Establish the relate environment:
ENTER COMMAND> RELATE 1
   <coverage>.PAT BY LPOLY# LINK RO
ENTER COMMAND> RELATE 2
   <coverage>.PAT BY RPOLY# LINK RO
Example 1: Identify geologic contacts. Select lines
   separated by polygons having different values for
   the geologic unit item (itemname). Then, calculate
   a value that will designate those arcs as geologic
   contacts (calculate for item GEOLCONTACT).
ENTER COMMAND> RES $1<itemname> NE
   $2<itemname>
ENTER COMMAND> CALC GEOLCONTACT = 1
Example 2: Thickness contour lines can be tagged
   by selecting those lines that lie between polygons
   having different thickness values. In this example,
   MINOR1 is the .PAT item for thickness values.
   Values for MINOR1 represent different thickness
   intervals (for example, where MINOR1 = 1, the
   thickness interval is 0–50 ft, and where MINOR1
   = 2, the thickness interval is 50–100 ft).
ENTER COMMAND> ASEL
ENTER COMMAND> RES ( $1MINOR1 = 1 AND
   $2MINOR1 = 2 ) OR ( $1MINOR1 = 2 AND
   $2MINOR1 = 1 )
ENTER COMMAND> CALC THICKCONTOUR =
   50
```

F–6. Checking for Tagging Errors

Although errors may be detected in ARCEDIT by selecting for the different label values and drawing each in a different color, it is generally much more efficient to use ARCPLOT to check for errors because ARCPLOT has polygon-fill capability. An AML may be executed that will draw the coverage and fill the polygons in selected colors. Execute the AML, here named "PLOT.AML," as follows:

```
Arc: &RUN PLOT.AML
NOTE: The ".AML" suffix can be omitted from the
   command. This AML contains the following com-
   mands:
ARCPLOT
MAPEXTENT <coverage>
SHADESET <shadesetname> (this command is
   optional)
POLYGONSHADES <coverage> <item>
   <lookup table (optional argument)>
ARCS <coverage>
&RETURN
```

The AML will execute the ARCPLOT commands to the terminal; the polygons will be shaded with colors and (or) patterns, and arcs will be drawn. These commands could also be issued interactively; if this is done, omit the &RETURN command. If a SHADESET is not specified, then the default shadeset will be used. In the POLYGONSHADES command, the values for the specified .PAT item are used as the shade symbol numbers to fill the polygons. This approach may not produce the desired result, commonly because, when the item values were assigned, the values were determined by some criteria other than to correspond to shadeset values that would produce the desired range of colors and patterns on the screen. Using the item values as shade symbol numbers can also cause problems if any of the values are outside the range of the shadeset. A color lookup table and, for some maps, a customized shadeset would improve plot legibility. The lookup table, explained in more detail below, specifies a shade symbol number for each item value.

An ARCPLOT screen display provides a good method for rapidly detecting errors. However, the final inspection of the map is commonly done on full-size hardcopy plots. To obtain a plot, generate a plotfile in ARCPLOT and execute the plotfile on a hardcopy device; we used an electrostatic plotter. An AML to execute the commands and create the plotfile is shown below:

```
ARCPLOT
DISPLAY 1039,2
<plotfilename (for example, #PLOT)>
SHADESET <shadesetname for plotter
   device>
MAPEXTENT <coverage>
MAPUNITS <units (for example, METERS)>
MAPSCALE <(for example, 1000000 for
   1:1,000,000-scale output)>
POLYGONSHADES <coverage> <item>
   <lookup table (optional argument)>
ARCLINES <coverage> <item> <lookup table
   (optional argument)>
QUIT
&RETURN
```

This AML is executed in the same way as PLOT.AML. As a default, colors and patterns for polygon interiors and arcs are determined by values for the specified item; those values are used as the hardware colors in the SHADESET file or line types in the LINESET file. For this AML, the default lineset (PLOTTER.LIN) is used and is, therefore, not specified. If a lookup table is specified as an argument to POLYGONSHADES or ARCLINES, then item values are related to selected hardware colors or line types listed in the lookup table. Lookup tables are extremely useful for customizing output, and they can be updated to change a plot's appearance. A lookup table can be created in INFO as follows:

```
ENTER COMMAND> DEFINE <lookup table
   name (for example, LOOKUP.TAB)>
```

```
Item name,width [,output width] ,type [,decimal
   places] [,protection level]
NOTE: When specifying format in the following dia-
   log, use "4 5 B" for "coverage item name" and
   for "symbol" and ensure that, in the attribute
   table, "coverage item name" has this format.
    1
ITEM NAME> <coverage item name
   (for example, COLOR)>
ITEM WIDTH> 4
ITEM OUTPUT WIDTH> 5
ITEM TYPE> B
    5
ITEM NAME> SYMBOL
ITEM WIDTH> 4
ITEM OUTPUT WIDTH> 5
ITEM TYPE> B
    9
ITEM NAME> <cr>
ENTER COMMAND> ADD
NOTE: Always set COLOR and SYMBOL to 0 (zero)
   for the first record of the file.
    1
COLOR> 0
SYMBOL> 0
    2
COLOR> 1
SYMBOL> 16
    3
. . . . . .etc. . . . . .
    4
COLOR> <cr>
ENTER COMMAND> LI
  $RECNO    COLOR    SYMBOL
     1         0         0
     2         1        16
     3         . . . . . .etc. . . . . .
ENTER COMMAND> Q STOP
```

The lookup table, LOOKUP.TAB, will use the values for item name COLOR to assign hardware shadeset values in SYMBOL. The item name must be specified as an argument to the POLYGONSHADES or ARCLINES command. To change values in the lookup table, use the UPDATE command in INFO. If an item name must be changed after the lookup table has been created, then use the ALTER command (see section F–7).

A particular lookup table may be useful for plotting coverages located in different directories. Rather than creating an identical lookup table in INFO in each of the other directories, attach to the destination directory, invoke INFO, and copy the lookup table from the source directory as follows:

```
ENTER COMMAND> ADIR <full pathname
   to source directory (for example,
   DRSOLLER>MT>INFO)>
ENTER COMMAND> TAKE DATA ARC <file
   name (for example, LOOKUP.TAB)>
```

F–7. Combining Coverages and Eliminating Sliver Polygons

This report is confined mostly to discussion of essential, basic techniques. However, the more specialized technique of combining several polygon coverages was required for processing our test map and may be of general interest. ARC has three commands that perform this operation under different rules: UNION, IDENTITY, and INTERSECT. Consult the ARC/INFO user's manual (volume 2) for details.

For the test map, separates showing the character of surficial deposits and the thickness of Quaternary sediments had to be combined into a coverage that contained all arcs of the two coverages. Therefore, the UNION command was generally used. This procedure merges the map data and attribute tables from two coverages. Because our procedure involves the use of the ELIMINATE command after UNION, we found it prudent to combine the separates before tagging arcs according to the procedures outlined in section F–5. ELIMINATE can remove polygon label points and certain arcs that describe spurious polygons generated during UNION; item values for arcs can, therefore, be affected by this command.

For some of our larger coverages, the UNION operation failed after encountering an arc intersection during the polygon-building phase of the operation. When UNION fails, the error message provides the intersection coordinates so that it can be corrected in ARCEDIT. To correct the error, invoke ARCEDIT and specify one coverage as the EDITCOVERAGE and the other as the BACKCOVERAGE. Specify DRAWENVIRONMENT ARC, NODE, LABEL and BACKENVIRONMENT ARC, NODE, LABEL. Do not draw the coverage yet, as drawing is unnecessary and time consuming. On the blank screen, find the approximate location of the arc intersection with the WHERE command (if the EDIT1.AML is being used, select "ARCEDIT command," then WHERE). Select MAPEXTENT * and define the box to include the intersection coordinates. Next, draw the coverage. Set parameters such as EDITDISTANCE (see section F–1) and locate the arc intersection coordinates with the WHERE command. If the problem lies in the EDITCOVERAGE, move the arcs as needed to prevent the UNION operation from failing again. If the problem lies in the BACKCOVERAGE, redefine the backcoverage as the new editcoverage and correct the problem. Save and quit ARCEDIT, BUILD the edited coverage, and retry the UNION operation. As a precaution against unexpected problems with polygon or arc attribute tables, perform the INFO update and IDEDIT procedure (see section F–3) on the rebuilt coverage before executing the UNION command.

On the second try, UNION may fail again after encountering another arc intersection. For our map project, the iterative process of editing the coverages and rerunning the UNION operation was lengthy: a successful UNION operation required, on some coverages, as many as 6 hours

to complete in batch mode. Large coverages that fail to be combined with UNION may be combined by using the INTERSECT command. INTERSECT performs the same type of operation as UNION, but it involves only the area in common between the two coverages. For our coverages, this was not a significant limitation, as both coverages were of the same size and had nearly identical neatline positions.

In the UNION and INTERSECT operations, attribute tables from the two coverages are compared and combined into a new attribute table. For identical items in the two coverages (for example, MINOR1), the item value for the INTERSECTCOVER or UNIONCOVER (see below) is placed into the new attribute table, and the item value for the other coverage is discarded. It may be desirable to retain certain items named the same in both source coverages, such as items that identify the type of geologic unit. If so, before executing the UNION or INTERSECT operation, change the item name(s) in one of the coverages, by using the ALTER command in INFO:

ENTER COMMAND> **SEL** <**coverage.PAT** *or* **coverage.AAT**>
ENTER COMMAND> **IT** *(item names and formats will be listed)*
ENTER COMMAND> **ALTER**
ITEM NAME> <**item**>
ITEM NAME> <**new item name**>
NOTE: After the item name(s) is (are) changed, the control-A escape sequence can be used to return the user to the INFO prompt. It is not necessary to change the item output width or other components of item format.
ITEM OUTPUT WIDTH> <**control-A**>
ENTER COMMAND> **Q STOP**

If the item format needs to be changed for some reason, the safest, and therefore probably the best, procedure is to add a new item having the desired format, calculate the values for the old item into the new item, and drop the old item from the attribute table.

After the attribute tables are checked, the UNION or INTERSECT command can be issued. The first three arguments of these commands are required: INCOVERAGE and UNIONCOVERAGE or INTERSECTCOVERAGE are combined to form OUTCOVERAGE. The fuzzy tolerance argument sets the minimum distance allowed between arc coordinates (that is, the map resolution) and need not be specified if the default value is acceptable. For coverages similar to the test map, the ARC/INFO rule for calculating the default fuzzy tolerance is (width of the BND)/10,000. Default tolerances for the map coverages were roughly 5 m. Considering that the map was compiled, and will be published, at 1:1,000,000 scale, we judged this level of resolution to be unnecessarily high. We selected a 50-m tolerance as a compromise between resolution and computer processing time. The last argument, JOIN or NOJOIN, specifies whether all items from both .PATs will be combined into the OUTCOVERAGE.PAT. We used JOIN, which is the default. For INTERSECT, the type of output coverage (POLY, LINE, or POINT) is specified in the fourth argument. We used POLY, which is the default.

As will be noted by comparison of the following dialog with examples given in the ARC/INFO manual, no input is required if the default value for an argument is chosen, unless it is followed by an argument for which the default value is not chosen. Then, # must be used to specify the default value.

Finally, the BUILD command must be issued to restore proper polygon topology. Because an .AAT is not created for the outcoverage, BUILD with the LINE option must also be used if an .AAT is desired.

Arc: *To guard against problems resulting from ARCEDIT and INFO processing of a source coverage prior to UNION or INTERSECT, it may be appropriate to execute the INFO update and IDEDIT procedure outlined in section F–3.*
Arc: **UNION** <**incoverage**>
<**unioncoverage**> <**outcoverage**>
<**fuzzy tolerance** *(for example,* **50**)>
. . . . . *or*. . . . . .
Arc: **INTERSECT** <**incoverage**>
<**intersectcoverage**> <**outcoverage**>
<**fuzzy tolerance** *(for example,* **50**)>
NOTE: The computer issues processing statements that require no response.
Arc: **BUILD** <**outcoverage**> **LINE** *(if an .AAT is desired)*
Arc: **BUILD** <**outcoverage**>

The .PAT of the combined coverage contains polygon internal number and -ID number items for both source coverages. In many cases, these items are no longer needed. Inspect the .PAT in INFO after executing the BUILD, and note the unneeded items. Quit INFO and drop those items.

UNION and INTERSECT cause the two coverages to be overlain and combined, forming many new polygons. Some of these polygons may be spurious artifacts of the process and should be deleted. Generally, these spurious polygons are narrow and small and are termed "sliver polygons." They are especially common where the source coverages contain lines in nearly the same position. For example, geologic contacts along the borders of a stream valley might be subparallel to, and in places coincide with, sediment thickness contours within the valley. When the geology and thickness coverages are combined, sliver polygons may be produced along the valley margins.

By nature, sliver polygons generally have small area-to-perimeter ratios. However, there is commonly a gradation, as well as some degree of overlap, between the population of sliver polygons and the population of polygons that are valid and should be retained. To eliminate

sliver polygons, an area/perimeter ratio must be selected that isolates most sliver polygons from the general polygon population. For this optimum ratio, some of the smallest valid polygons may fall within the sliver polygon population, but that is unavoidable and generally of little consequence. The optimum ratio is best selected visually, perhaps by using the following technique:

```
Arc: ADDITEM <coverage>.PAT
   <coverage>.PAT RATIO <format
   (for example, 4 12 F 3)>
Arc: INFO
ENTER COMMAND> SEL <coverage>.PAT
ENTER COMMAND> CALCULATE RATIO =
   AREA / PERIMETER
ENTER COMMAND> Q STOP
Arc: ARCPLOT
ARCPLOT: MAPEXTENT <coverage>
ARCPLOT: ARCS <coverage>
ARCPLOT: SHADESET <shadesetname>
   (if default is not acceptable)
ARCPLOT: ASEL <coverage> POLY
ARCPLOT: RESEL <coverage> POLY RATIO
   < 50 (or some other value)
ARCPLOT: POLYGONSHADES <coverage> 2
   (polygons for which RATIO is <50 are filled with
   the shadeset's color 2)
ARCPLOT: NSEL <coverage> POLY
ARCPLOT: RESEL <coverage> POLY RATIO
   < 60
ARCPLOT: POLYGONSHADES <coverage> 3
ARCPLOT: ASEL <coverage> POLY
ARCPLOT: RESEL <coverage> POLY RATIO
   < 60
ARCPLOT: NSEL <coverage> POLY
ARCPLOT: RESEL <coverage> POLY RATIO
   < 70
ARCPLOT: POLYGONSHADES <coverage> 4
ARCPLOT: ASEL <coverage> POLY
. . . . . .etc. . . . . .
```

This technique allows the user to interactively display polygons having different area/perimeter ratios and to select the most appropriate ratio. For some maps, the user may need to clear the screen, redraw the arcs, and then select and draw polygons by using a range of ratios different from that used in the first trial.

Sliver polygons are eliminated with the ELIMINATE command. In the following example, we assume that "RATIO = 60" is the optimum choice:

```
Arc: ELIMINATE <coverage> <outcoverage>
NOTE: The computer issues processing statements
   that require no response.
>: RES RATIO < 60
>: <cr>
Do you wish to re-enter expression (Y/N)? N
Do you wish to enter another expression (Y/N)? N
  1406 features out of 8530 selected.
Number of Polygons  (Input,Output) =  8530  7209
Number of Arcs      (Input,Output) = 19111 17780
  Creating OUTCOVERAGE.PAT
Arc: BUILD <outcoverage>
Arc: perform INFO update and IDEDIT (see section
   F–3)
```

F–8. Unsplitting Arcs

Certain coverages may contain many pseudonodes, which may be detected with ARCEDIT's DRAWENVIRONMENT NODE or DRAWENVIRONMENT NODE PSEUDO option. This variety of node separates but two arcs. Pseudonodes are used to separate arcs that contain more than 500 coordinates, which is the maximum number of coordinates, or vertices, per arc allowed by ARC/INFO.

Pseudonodes can also be generated by other procedures in ARC/INFO, such as extensive editing of arcs or using the ELIMINATE command to remove sliver polygons. In these cases, a single arc could replace two or more arcs separated by pseudonodes. If sliver polygons have been removed with the ELIMINATE command, or if extensive editing has produced many pseudonodes, we recommend that pseudonodes be removed with the UNSPLIT command. This command may significantly reduce the file size and, hence, plotting and processing time. The UNSPLIT command removes pseudonodes between arcs having the same "<coverage>-ID" number. Therefore, before unsplitting, the <coverage>-ID numbers must be recalculated. After the unsplit operation, the coverage's topology must be rebuilt. If arcs have been tagged interactively to identify a certain attribute (for example, type of geologic contact), then UNSPLIT should be performed only before arc tagging, because when UNSPLIT removes a pseudonode and combines two arcs, item values for one arc are retained and values for the other arc are discarded. If, however, arcs are tagged automatically, as discussed in section F–5, UNSPLIT can be performed at any time and can be followed by arc retagging.

When executed on a large file containing many pseudonodes, the UNSPLIT command may require several hours, or even days, to complete. It may be most efficient to perform this operation from an AML (UNSPLIT.AML shown below) executed in batch mode.

```
Arc: &R UNSPLIT
This AML could consist of the following commands:
ARCEDIT
EDITCOVERAGE <coverage>
EDITFEATURE ARC
GRAPHICS OFF
SNAPDISTANCE 0
NOTE: In the following example, all arcs in the cov-
   erage are selected for unsplitting. Unsplitting can
   also be performed on a selected subset of arcs.
   To do so, use the SELECT FOR command.
SELECT ALL
```

CALC <**coverage**>**-ID = 99** *(or some other unique value)*
UNSPLIT
SAVE
QUIT
&RETURN
NOTE: After the AML has executed, rebuild the coverage, and perform the INFO update and IDEDIT (see section F–3).

This procedure can also be run interactively, although that would be most appropriate only for coverages of relatively small file size. To do so, specify the display and terminal device number (see section D), enter ARCEDIT, and execute all the above commands except &RETURN.

G. Generating Color Separates for Map Printing

Before the user begins to create color separates, each coverage should be fully edited. Next, each coverage must be converted to the proper format for the device that will generate the color separates. For our purposes, the Scitex Response-280 editing workstation and plotter are the devices of choice because they can process large-format maps and can produce high-quality printing screens. This section covers ARC/INFO's format conversion commands, a brief overview of processing procedures used by the Scitex Response-280 system, and ARC-to-DLG format conversion. The discussion is not sufficiently detailed to be a user's manual for the Scitex; instead, it is a general introduction to Scitex map-processing procedures.

G–1. Converting Map Data from ARC/INFO to Scitex Format

ARC/INFO coverages can be converted into Scitex Response-280 format files by the ARCSCITEX command and by the PLOTSCITEX command. ARCSCITEX converts one or more ARC/INFO coverages to Scitex format. PLOTSCITEX converts an ARCPLOT plotfile generated from a coverage or group of coverages. The two commands provide different approaches to map preparation but can produce the same map product. The appropriate command should be chosen after consultation with Scitex personnel.

We chose to convert the coverages with ARCSCITEX. Many conversion parameters can be specified in ARCSCITEX; the following dialog shows the basic commands we used to convert our map coverages:

Arc: **ARCSCITEX** <**desired prefix for all Scitex-format output files** *(for example,* **GEOL**)>
Arcscitex: **COVERAGE** <**coverage name**> <**LINE**>
Arcscitex: **LINEFONT** <**item**>
NOTE: Values for the item specified in the LINEFONT command are passed to Scitex in the DIGIT file with line coordinate information. The item values may range from 1 to 999. The EXECUTE command clears the current LINEFONT command.
Arcscitex: **STATUS** *(use if desired to check the status of all conversion arguments)*
Arcscitex: **PAGESIZE** <**width**> <**height**>
NOTE: We used a page size slightly larger than the anticipated map dimensions at our specified map scale. Specify page size in inches (the default unit); if another unit of measure is desired, specify it with the PAGEUNITS command.
Arcscitex: **MAPSCALE** <*(for example,* **1000000** *for 1:1,000,000-scale output)*>
Arcscitex: **MAPEXTENT** <**coverage name**>
Arcscitex: **RESOLUTION** <**rasters or pixels per millimeter** *(for example,* **17**)>
Arcscitex: **EXECUTE**
Conversion of Line coverage "COVERAGE NAME" completed.
Arcscitex: **COVERAGE** <**coverage name**> <**POLY**>
Arcscitex: **AREAFONT** <**item**>
NOTE: Values for the item specified in the AREAFONT command are passed to Scitex in the TEXTEDIT or ARF file (area reference file) with the coordinates of label points for polygons and are used to assign colors and (or) patterns (area-fill fonts) for Scitex area filling. For most map applications, the item values represent different map units or color screen values. Values must correspond to available Scitex color channels (1–12), or they must be converted to Scitex color channel values by means of the RELATE command and a lookup table. The EXECUTE command clears the current AREAFONT command.
Arcscitex: **EXECUTE**
Conversion of Polygon coverage "COVERAGE NAME" completed.
Arcscitex: **QUIT**
Creating ARF files for each partition...
Sorting DIGIT attributes...
Generating output report...
Leaving ARCSCITEX...
Arc:

In the above dialog, three files were generated by ARCSCITEX. The first, initiated by the COVERAGE command with the LINE option, is a Scitex DIGIT file, GEOL.DIG, containing the linework; the suffix .DIG refers to a DIGIT file. In Scitex operations, DIGIT files are labeled as type 310 files. The second file, initiated by the COVERAGE command with the POLY option, is a Scitex TEXTEDIT or ARF file, GEOL_DEFAULT.ARF, containing the label points; the suffix .ARF refers to a Scitex area reference file. In Scitex, TEXTEDIT files are referred to as type 102. For each ARC/INFO label point, the TEXTEDIT file contains a pair of x- and y-coordinates and a color channel or pattern name (for example, 1375,2932,5 or 1375,2932,pattern name) determined by the item speci-

fied in ARCSCITEX. The third file is an output report (GEOL.RPT).

On the Scitex, many thematic maps are plotted at a resolution of 17 rasters, or pixels, per millimeter, also referred to as RES17. This setting provides a good compromise between file size and resolution and captures line positions with an accuracy equal to that of conventional trace scribing. For color on thematic maps, the USGS uses RES34 screens as its standards. Screens of lower resolution produce a noticeably lower quality image. For thematic maps processed at RES17, screens can be plotted at RES34 by specifying 2 in response to the dialog prompt for the number of screen elements per pattern element. The Scitex SCREENLIB command allows storage in a disk library of as many as six screens. Commonly, four screens are required (yellow, magenta, cyan, and black), and they are set at angles of 90, 15, 75, and 45 degrees, respectively.

The Scitex has 12 color channels; commonly 1 channel is reserved for the linework, 1 is reserved for the background color, and 10 channels are assignable to map-unit colors. A TEXTEDIT file, therefore, can contain only 10 different map units to be filled with color. If a coverage contains more than 10 map units, then more than one TEXTEDIT file is required. The part of the Quaternary sediments map scanned for testing our method contains more than 10 map units; they belong to four thematic categories or groups, each having fewer than 10 different units. Therefore, the coverage to be output to Scitex was copied four times. Values for the geologic unit item in the .PAT were modified for each new coverage to create four different polygon coverages, one for each group of map units. Because the first of the new coverages will show label point information only for polygons of the first group, the geologic unit item for all other label points was recalculated to zero. The polygons in the first group were recalculated to values between 1 and 10, in order to correspond to the Scitex color channels. This procedure was applied to the other three coverages. In the ARCSCITEX subroutine, the COVERAGE command with the LINE option was executed once, and then the four new coverages were each executed with the POLY option. This processing could be done as follows:

NOTE: For this example, a coverage named "GEOL" has more than 10 map units, naturally divisible into four thematic categories or groups, each having fewer than 10 different map units. The item containing the map unit identifier is GEOLOGY; item values range from 101 to 108 (group 1), from 201 to 208 (group 2), from 301 to 308 (group 3), and from 401 to 408 (group 4). To format the coverage for the Scitex, copy the coverage four times, invoke INFO and select the first new coverage, set the GEOLOGY item values for groups 2 to 4 to zero, perform an NSEL to reselect group 1, and recalculate the group 1 item values so that values range from 1 to 10 (or less).

```
Arc: COPY GEOL GEOL1 (then repeat for GEOL2, GEOL3, GEOL4)
Arc: INFO
ENTER COMMAND> SEL GEOL1.PAT
ENTER COMMAND> RES GEOLOGY LT 101 OR GEOLOGY GT 108
ENTER COMMAND> CALC GEOLOGY = 0
ENTER COMMAND> NSEL
ENTER COMMAND> CALC GEOLOGY = GEOLOGY - 100
NOTE: Perform similar calculation on other coverages, resulting in four coverages created from the source coverage, each having GEOLOGY item values ranging from 1 to 10 for only one map group.
ENTER COMMAND> Q STOP
Arc: ARCSCITEX <desired prefix for all Scitex-format output files (for example, GEOL)>
Arcscitex: COVERAGE GEOL LINE
Arcscitex: LINEFONT <item>
Arcscitex: PAGESIZE <width> <height>
Arcscitex: MAPSCALE <scale>
Arcscitex: MAPEXTENT GEOL
Arcscitex: RESOLUTION <(for example, 17)>
Arcscitex: EXECUTE
Arcscitex: COVERAGE GEOL1 POLY
Arcscitex: AREAFONT GEOLOGY
Arcscitex: EXECUTE
Arcscitex: COVERAGE GEOL2 POLY
Arcscitex: AREAFONT GEOLOGY
Arcscitex: EXECUTE
. . .Repeat for each coverage. . .
Arcscitex: QUIT
Arc:
```

The four TEXTEDIT files created from the test map must later be processed on the Scitex into color separate files in order to generate the color screens. Because the Scitex is configured as a single-user system, any processing, whether interactive or in batch mode, prevents the Scitex editing workstation from being used for other purposes. More map projects could be processed with greater efficiency if the processing into color separate files were done on the ARC/INFO coverages before conversion to Scitex format; computers that run ARC/INFO are more common than Scitex editing workstations and can more readily accommodate the extra processing task. Scitex represents a data-processing bottleneck, is a system not readily accessible or usable by most thematic map project personnel, and may entail significant processing-related expenses. It may, therefore, be desirable to add items to the .PAT in ARC/INFO for each of the color channels and to calculate the proper screen values into each color channel item. This procedure is easily performed in an AML. In the following example, information on the geologic map units is contained in the item MINOR3. MINOR3 values of 101–110, 201–210, 301–310, and so on, are categories of genetically related map units. Map units in a category have similar colors and are treated as a group in the AML.

```
Arc: ADDITEM <coverage>.PAT
   <coverage>.PAT (! <items for color
   separates (for example, YELL,RED,CYAN,
   BLK,BRN)> !) <format (for example,
   4 5 B)>
Arc: &R COLORSEP.AML
NOTE: The COLORSEP.AML could contain the com-
   mands and logic shown below:
&DATA ARC INFO
SEL <COVERAGE>.PAT
CALC YELL = 0
CALC RED = 0
CALC CYAN = 0
CALC BLK = 0
CALC BRN = 0
RES MINOR3 GE 101 AND MINOR3 LT 200
CALC YELL = 7
CALC RED = 1
CALC CYAN = 1
CALC BLK = 1
CALC BRN = 1
RES MINOR3 GT 101
CALC YELL = 10
CALC RED = 11
RES MINOR3 GT 102
CALC RED = 3
RES MINOR3 GT 103
CALC RED = 6
RES MINOR3 GT 104
CALC YELL = 5
CALC RED = 10
ASEL
RES MINOR3 GE 201 AND MINOR3 LT 300
. . .Follow the logic shown above to identify other
   appropriate color values. . .
Q STOP
&END
&RETURN
```

However, passing screen values, rather than map-unit values, to Scitex does have a drawback: the color separate files (discussed below) cannot be used to check for multiple definitions (multiple label points in a polygon) or for unfilled areas of a polygon separated from the label point by a narrow area, or bottleneck. A multiple definition commonly points to an error in the data set or to a label point that, upon conversion to Scitex, no longer falls within the bounds of the polygon. For many maps, this check for multiple definitions may not be a serious loss because errors can be detected in the color proof.

For maps with many narrow polygons and unfilled areas, this procedure may be inappropriate; the time needed to fill the areas with color for each color separate may be far greater than the time needed to process a coverage into color separates by using the COMBSEP command and PLACR batch command (see section G–3). However, for such maps, the number of unfilled areas can be greatly reduced, and the use of this procedure justified, by executing the ARCSCITEX command with a high resolution (for example, RES34 as discussed in section G–3). The high resolution will produce smaller pixels upon execution of the DIGIT file to a 1-pixel-width line file and will, therefore, produce fewer bottlenecks and unfilled areas.

G–2. Transferring the Scitex-Format Files from ARC/INFO to Scitex

ARC/INFO's SCITEXWRITE command was used to write the files to magnetic tape in a format that can be read by a Scitex Response-280 editing workstation. The SIF (standard interchange format) option should not be used. The tape is read onto the Scitex with the TCOPY command. Proper responses to TCOPY prompts are as follows:

```
ENTER FILE LIST: <filename>: <file type (enter
   310 for a DIGIT file, 102 for a TEXTEDIT file)>
FILE BLOCK FORMAT: FIX
SWAP BYTES: NO
```

G–3. Scitex Processing to Produce Color Separates

The Scitex DIGIT and TEXTEDIT files must be processed to produce color- and (or) pattern-filled polygons. After the user has checked for completeness and quality of the color fill, the files can be processed into files that each contain the patterns or screen percentage information required for the Scitex to plot each color separate. Before the polygons are filled with color, the DIGIT file, also known as the "color boundary file," must be rasterized so that lines are 1 pixel wide; use the DIGIT command with the EXC or VTR (vector-to-raster) option. We first tried this at RES17, but, because our linework is tightly spaced, some of the lines were not properly positioned for a successful polygon-fill operation. We executed (rasterized) the DIGIT file again at RES34, which rectified most of the polygon-fill errors. The rasterized line file should then be checked for line breaks with the FINDEP (find endpoint) command, which finds endpoints of single-pixel-width lines. Line breaks can be closed interactively.

Before proceeding further, the user should check the rasterized line file for proper scaling and registration. The line file must be at the same scale as the base map with which it will be combined for printing, and it should register to all other files (for example, color-fill files) used to print the map. Because the Tektronix scanner and the Scitex plotter may differ in their calibration, it is advisable to check for proper scaling of Tektronix-scanned files (and for Scitex-scanned files as well, unless the scanner and plotter are calibrated precisely the same). Manipulation of data in ARC/INFO (for example, by the PROJECT or TRANSFORM commands) may also change map dimensions sufficiently that rescaling is required before the scanned map will fit the base map. To facilitate rescaling, ensure that all ARC/INFO coverages contain some registration marks as

arc features (such as the neatline, registration marks outside the map area, or a shoreline shared by the base map and all coverages), unless rescaling will be checked by registration to the author's inked linework on the base map.

To check for proper scaling, compare a Scitex-generated clear film plot of the line file to a scale-stable copy of the base map or to a scale-stable copy of the author's linework that registers to the base map. If the plot does not register precisely to the author's linework or to the base map, then the required increase or decrease in both the x- and y-dimensions should be measured to the nearest thousandth of a millimeter. Dimensions must be measured in inches, unless another unit of measure was specified in ARCSCITEX.

When the proper x- and y-dimensions are known, the line file can be rescaled by using either of two approaches. Because the physical size of the line plot is governed by the size of the blank pattern upon which Scitex places the raster line image, the most accurate method of resizing the line file is by creating a new blank pattern of the proper dimensions. Then, use the DIGIT command to create a new raster line file from the DIGIT file; the new line file will be sized in accordance with the new blank pattern. A similar result can be obtained by merely rescaling the line file when plotting. This rescaling may produce lines of slightly lower quality, although they may still be accurate enough for many applications. Using either method, create a plot of the raster line file with the x- and y-dimensions adjusted, and check the plot against the base map. Rescale as needed. If all coverages were registered properly in ARC/INFO, these scaling factors should suffice for all files. The TEXTEDIT files cannot, however, be rescaled. Color-fill files generated from a TEXTEDIT file can be rescaled during plotting by using the scaling factors for the newly sized blank pattern.

The polygons are filled by colors and (or) patterns by the ARF (area reference file) command. This command associates the edited, 1-pixel-wide lines of the raster line file created from the DIGIT file with a TEXTEDIT file and uses the lines as boundaries between colors or patterns. A point of color or pattern is placed at the coordinate pair location and is then repeated in all directions until stopped by the 1-pixel-wide line. Multiple definitions are identified by the ARF command and can be corrected. Because we had four TEXTEDIT files, we executed ARF four times in batch mode with the USGS-written FILLR batch command.

The polygon-fill files created by the ARF or FILLR command should be overlain to check for errors: some polygons may be without a coordinate pair (an ARC/INFO label point) and, hence, are not filled, or polygons may have more than one coordinate pair (a multiple definition) and, hence, are filled with the wrong color. As noted above, if color screen values are passed to Scitex rather than values representing the map unit, this discussion is not applicable; errors must be checked in the color proofs. A USGS-written batch command, PLACR, checks for these problems. This batch should be run on copies of the color-fill files because it overwrites the color values for each raster location.

PLACR writes the first file to the Scitex work area and assigns channel 1 to all raster locations within the polygons that were color filled. For areas not to be filled, rasters are assigned channel 12 (background). Next, all raster locations in the second file that should be colored (that is, that occur in color-filled polygons) are assigned to channel 2. File 2 is digitally compared with file 1, and rasters in channel 2 are changed to channel 3 if they coincide with rasters in file 1 colored by channel 1. All raster locations in file 2 coinciding with rasters not to be plotted in file 1 (background, or color channel 12) are reassigned to channel 1. File 3 and subsequent files are modified by the procedures used to modify file 2. If file 3 contains a colored raster that coincides with a colored raster of files 1 or 2, then the file 3 rasters are reassigned, not to channel 3, but to channel 4. If this error occurs in subsequent files, the channel assignment increases accordingly.

To detect areas unfilled by any of the files, paint the map margin with a nonbackground color; this PLACR option is performed after all files are placed together so that unfilled areas can be found by searching for the background color inside the map. To find the unfilled areas, run the NODES command to search for channel 12, the background color. Unfilled areas may result from incorrect color channel values or from constricted polygons. Scitex fills a polygon with color by starting at the coordinate pair and filling outward in all directions; lines may be so tightly spaced that they inhibit filling of the entire polygon. That part of a polygon beyond the constriction will, therefore, remain unfilled. For our test map, very few multiple definitions or unfilled polygons were encountered.

After identifying an unfilled map area, add coordinates and the appropriate color channel value for a single point to the corresponding TEXTEDIT file or interactively fill the polygon on the Scitex. For some constricted polygons, it may also be wise to update the ARC/INFO coverage by dividing the polygon at the constriction and forming two polygons having identical attributes. For the intervening line, the "line type" item in the .AAT should be coded such that, if passed with the DIGIT file by the LINEFONT command at some time in the future, it will not be plotted on the Scitex (see discussion of Font Library below). Updating the ARC/INFO coverage to remedy the color-fill problems detected on the Scitex might prove helpful for workers who intend to update their map data base and print revised versions.

After all colors and patterns have been placed correctly, the proper Scitex output color codes should be placed into a batch file. Color separate files are then produced from the ARF-generated files, one color separate file for each printing color. The Scitex command COMBSEP performs this conversion. This step is not necessary if

the color separate information was added to the ARC/INFO coverages and passed to Scitex as the color channel values in TEXTEDIT files; the PLACR routine is also not necessary. For well-constructed and carefully edited ARC/INFO map coverages, the substantial decrease in Scitex computing requirements caused by adding color channel items in ARC/INFO may outweigh the advantages of the computerized error-checking inherent in PLACR.

A color separate file can also contain linework information. Lines may be colored and symbolized on the basis of the Scitex channel number; this number can contain values for an .AAT item value passed from ARC/INFO to the Scitex DIGIT file. A Scitex Font Library should be created, containing only the line characters (for example, a solid line 0.015 in. wide) and colors to be plotted. The item values for lines not intended for plotting (that is, scratch boundaries between certain map units) will not be listed in the Font Library and will not be plotted. When the DIGIT file is rasterized, the Font Library is accessed to produce the symbolized lines. An ARCPLOT plotfile, transferred to Scitex with the PLOTSCITEX command, can also be used to generate the symbolized lines. When this plotfile is used, an appropriate Scitex line weight is assigned to the DIGIT file before it is rasterized.

Prior to generation of color separates (negatives), the validity of the Scitex raster map is commonly checked on a color plot from an electrostatic plotter. For such plotters in use at the USGS, resolution is roughly equivalent to RES4 on the Scitex. For plotting, the color-fill files should be rescaled to reduce the number of pixels to that appropriate to RES4. This rescaling will greatly increase plotting speed. The line files need not be rescaled.

G–4. Converting ARC/INFO Coverages to DLG Format and Outputting to Tape

For certain map production procedures, ARC/INFO coverages may need to be reformatted into digital line graph files (DLG's). The ARC/INFO command ARCDLG does this, producing DLG-3 optional format files. The command has several optional arguments. As will be noted by comparison of the following dialog with examples given in the ARC/INFO manual, certain arguments are not needed to convert certain coverages (for example, the "pointcover" argument is not needed if a polygon coverage is to be converted to a DLG). The unneeded arguments should be represented in the command string by a #. For polygon or line coverages, we used the command with selected arguments, as follows:

```
Arc: ARCDLG <polygon or line coverage>
     <DLG filename> # # # <projection file>
     # # <header file> NOTRANS
```

The ARCDLG command will not allow a point coverage to be converted to a DLG. A point coverage may, however, become part of a DLG if it is appended to a polygon or line coverage as follows:

```
Arc: ARCDLG <polygon or line coverage>
     <DLG filename> <point coverage> # #
     <projection file> # # <header file>
     NOTRANS
```

The header for a DLG contains information on the corner tics and projection parameters. This information is passed to the DLG by the projection and header files, which are created by the user. Their file contents and formats are shown below. For full information, consult the ARC/INFO manual.

For a map area in the Northeastern United States, the projection file may appear as follows:

```
INPUT
PROJECTION LAMBERT
UNITS METERS
ZONE 61
PARAMETERS
40 40 00
43 20 00
-81 00 00
42 00 00
0.0
0.0
END
```

For the same map area, the header file may appear as follows:

```
MAPNAME THICKNESS
CATEGORY HYPSOGRAPHY
SOURCEDATE 1989
RESOLUTION 25.40
SCALE 1000000
CONTROLPOINT SW  40.00  -84.00
   -256222.000  -217600.800
CONTROLPOINT NW 44.00  -84.00
   -240658.800  226384.500
CONTROLPOINT NE  44.00  -78.00
   240657.800  226384.600
CONTROLPOINT SE  40.00  -78.00
   256221.600  -217697.400
```

The DLG must commonly be written to magnetic tape in ASCII format. From PRIMOS, files are commonly written to tape by the WRITE option of the MAGNET subroutine. However, unless otherwise specified, this command produces a tape file that does not strictly conform to industry standards for ASCII. It can be read back into PRIMOS with no problem, but it cannot be successfully read by other computer systems. The following CPL, written by Carl L. Rich (USGS), specifies the proper, industry-standard ASCII format:

```
&ARGS FILENAME; FILENUM
&IF [ NULL %FILENAME%] &THEN &DO
  TYPE
  TYPE USAGE: <cpl name> <dlg.filename>
      <magnetic tape file number>
  TYPE
  &RETURN
&END
&IF [NULL %FILENUM%] &THEN &S FILENUM := 1
&IF [EXISTS %FILENAME% -FILE] &THEN &DO
  TYPE
  TYPE File %FILENAME% does not exist
  TYPE
  &RETURN
&END
&DATA MAGNET
  DECLARE TAPE TAPE=(0),LRECL=
      (80),BFACTOR=(100),BUFFERS=(1)
  MODIFY TAPE DENSITY=(6250),FILENO=
      (%FILENUM%)
  DECLARE DISK DISK=(%FILENAME%),LRECL=
      (80)
  TRANSLATE TAPE (A*)
  WRITE DISK TAPE
  QUIT
&END
&RETURN
```

The CPL is invoked as follows:

```
OK, CPL <cpl name> <dlg.filename> <magnetic
   tape file number>
```

REFERENCES CITED

Aronoff, Stanley, 1989, Geographic information systems; A management perspective: Ottawa, Canada, WDL Publications, 294 p.

Soller, D.R., in press a, Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains—Northeastern States, the Great Lakes, and parts of southern Ontario and the Atlantic offshore area (east of 80° 31′ west longitude): U.S. Geological Survey Miscellaneous Investigations Series Map I–1970–A, scale 1:1,000,000.

———in press b, Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains—Northern Great Lakes States and Central Mississippi Valley States, the Great Lakes, and southern Ontario (80° 31′ to 93° west longitude): U.S. Geological Survey Miscellaneous Investigations Series Map I–1970–B, scale 1:1,000,000.

———in press c, Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains—Northern and Central Plains States (90° to 103° west longitude): U.S. Geological Survey Miscellaneous Investigations Series Map I–1970–C, scale 1:1,000,000.

———in press d, Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains—Northern Plains States (west of 103° west longitude): U.S. Geological Survey Miscellaneous Investigations Series Map I–1970–D, scale 1:1,000,000.

Utz, L.G., Cialek, C.J., Lawson, H.S., and Doughty, E.F., 1988, Technique development for digital production of a Quaternary sediment map: American Congress on Surveying and Mapping (ACSM)–American Society for Photogrammetry and Remote Sensing Fall Convention, Virginia Beach, Va., Sept. 11–16, 1988, ACSM Technical Papers, p. 162–167.

APPENDIX, DESCRIPTION OF THE PROTOTYPE METHOD

Linework for the test map consists of inked compilations on four scale-stable film positive separates. To convert these separates to a digitally produced map, a prototype method was devised to use hardware and software available at the U.S. Geological Survey (C.J. Cialek, USGS, written commun., 1987; Utz and others, 1988). This prototype method, with steps 15–22 modified slightly by Soller during data processing, is briefly summarized below and in figure A–1. Only steps 14–23 can be performed by the map author or project scientist.

(1) Author-drafted linework for each of the four separates is prepared for digital scanning by removal of map symbols and their leaders and touchup of linework. A wipe-on color proof is used as the scan copy. This copy contains linework in black, the cultural base in yellow, and the quadrangle border and neatline in red. The quadrangle corners are used later to project the coverages for Scitex and Intergraph editing.

(2) A raster scan of each separate is performed on a Scitex Super Color Scanner at RES17 or RES34 (17 or 34 Scitex pixels per millimeter).

(3) Raster files are thinned to 1-pixel width, edited, and vectorized on the Scitex editing workstation.

(4) Files are written to magnetic tape.

(5) Each file is loaded onto the DLG (digital line graph) processor, a computer where the files are converted to DLG format by use of the National Mapping Division's (NMD's) PROSYS[1] software. The Scitex vector file contains only scanned lines; PROSYS checks for errors in lines (for example, intersections), establishes topology, and adds area labels.

(6) Each DLG is written to magnetic tape.

(7) The tape is loaded onto an Intergraph computer and converted via NMD's RETSAM[2] software to Intergraph format.

(8) On the Intergraph editing workstation, and with the aid of commands assigned to tablet menus, proper attribute values are assigned to each polygon interactively, and additional linework editing is done as needed.

(9) The validity of each file is checked on electrostatic plots.

(10) Each file is converted to Altek data format by RETSAM software.

(11) Files are written to magnetic tape.

(12) Files are read into the DLG processor for restructuring by PROSYS software and for creation of DLG-formatted output. If PROSYS detects errors in a file, steps 5–12 must be repeated until all errors detected by PROSYS are eliminated.

(13) Standard-format DLG's are written to magnetic tape.

(14) Tape is copied to the disk of a computer that has ARC/INFO GIS software.

(15) DLG's are converted to ARC/INFO format; each DLG file becomes an ARC/INFO coverage. DLG's containing both point and line information (for example, the miscellaneous point and line map separate) will be separated into two coverages. The ARC/INFO command DLGARC is designed to convert a DLG into one or more ARC/INFO coverages. However, our maps had to be converted by a program ("CDLG.AML") written by one of the authors (Lanfear) because the DLGARC converter in ARC/INFO could not read the DLG's we were provided.

(16) Prior to ARC/INFO editing, all coverages for a given quadrangle (surficial, thickness, subsurface, and miscellaneous point and line data) must be precisely registered to each other; for some quadrangles, the TRANSFORM command in ARC or the ADJUST command in ARCEDIT was required to distort or "rubber-sheet" coverages into proper registration.

(17) In ARCEDIT, lines and polygon labels are checked and edited as needed. Editing efficiency is improved through the use of a customized AML (Arc macro language) program with pulldown menus, which was written by one of the authors (Lanfear).

(18) The validity of map data is checked in ARCPLOT on a graphics display terminal. After any errors have been corrected in ARCEDIT, electrostatic plots are generated for a final check.

(19) Two coverages, character of surficial deposits and thickness of Quaternary sediment, are combined so that resultant polygons contain information from both coverages, and can, therefore, be assigned unique map colors. Coverage items are renamed as appropriate; then the coverages are merged by the UNION or INTERSECT command, and sliver polygons (artifacts of combining coverages in which lines are nearly parallel) are removed by the ELIMINATE command. This procedure is explained in section F–7.

(20) The validity of map data is checked in ARCPLOT on a graphics display terminal. After any errors have been corrected in ARCEDIT, electrostatic plots are generated for a final check.

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[1]Information on PROSYS is available from the USGS, 526 National Center, Reston, VA 22092.

[2]Information on RETSAM is available from the USGS, 562 National Center, Reston, VA 22092.

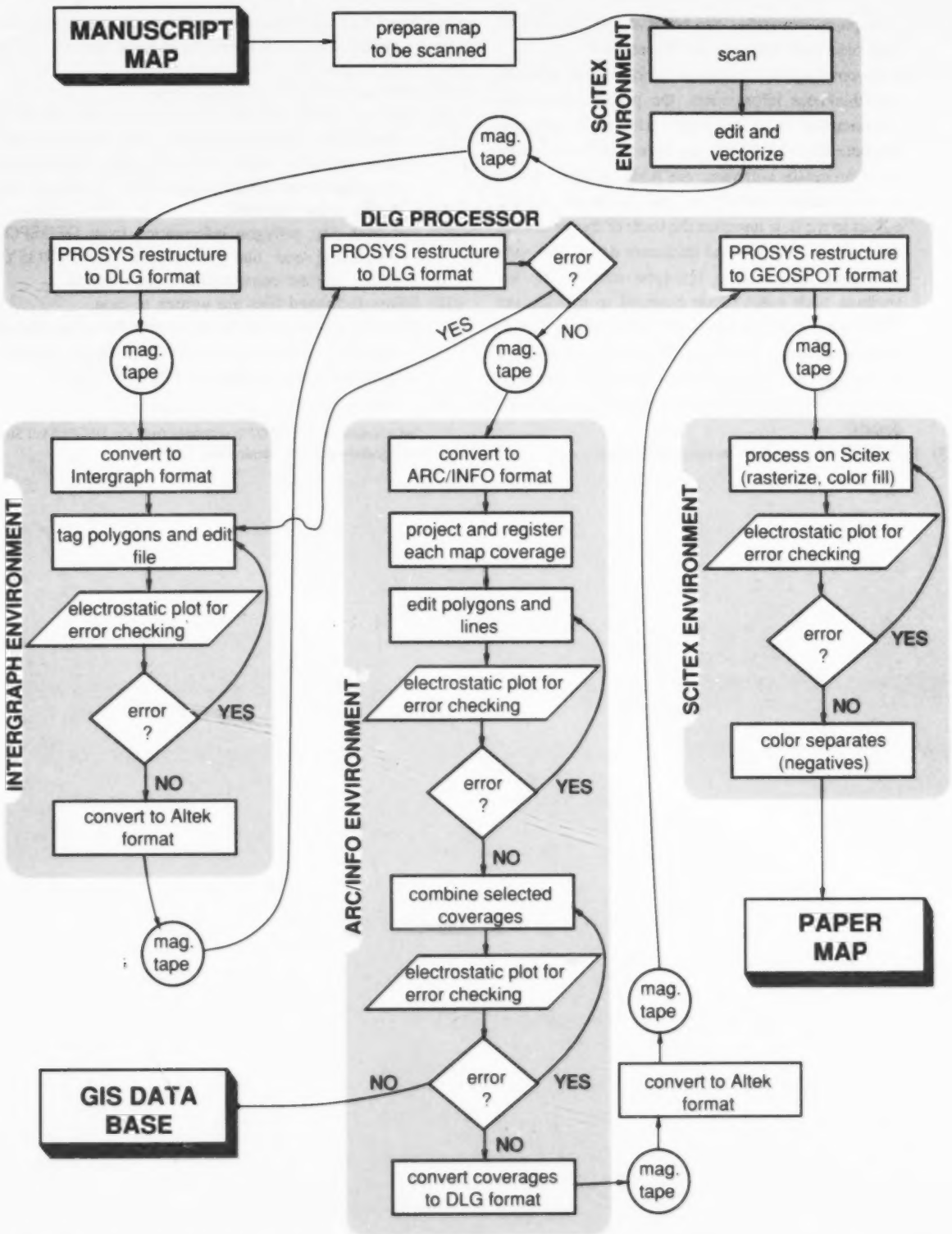

Figure A–1. Steps in digital production of maps by the prototype method. Diagram modified from C.J. Cialek (U.S. Geological Survey, written commun., 1987). DLG, digital line graph; mag., magnetic; GIS, geographic information system.

(21) At this point, coverages can be developed into a GIS data base (not discussed in this report).

(22) For the coverage that contains the combined surficial and thickness information, the polygon attributes are renamed. New items are added to the polygon attribute table (.PAT) in the format required by the DLG processor software. An AML written by one of the authors (Soller) is used to assign unique values to the new items on the basis of the values for the surficial deposits and thickness items. For each coverage, values for a line-type item in the arc attribute table (.AAT) are changed to provide the appropriate code for line type (for example, solid, scratch, dashed). Each coverage is then converted to optional DLG format via the ARCDLG command with the NOTRANS option (see section G–4 for details).

(23) The DLG's are written to magnetic tape.

(24) The DLG's are read onto an Intergraph computer and modified to Altek format to become readable by the DLG processor.

(25) Files are written to magnetic tape.

(26) Files are loaded onto the DLG processor for PROSYS structuring. Polygon attribute codes (the new .PAT item values in step 22) are converted to a format translatable by NMD's GEOSPOT[3] software into Scitex color channels.

(27) For each file, polygon information from GEOSPOT processing and line information from PROSYS processing are converted to Scitex format.

(28) Scitex-formatted files are written to tape.

(29) Files are read onto the Scitex system for generation of negatives. This procedure can be lengthy and complex and is briefly discussed in this report.

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[3]Information on GEOSPOT is available from the USGS, Mail Stop 531, 345 Middlefield Road, Menlo Park, CA 94025.

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